



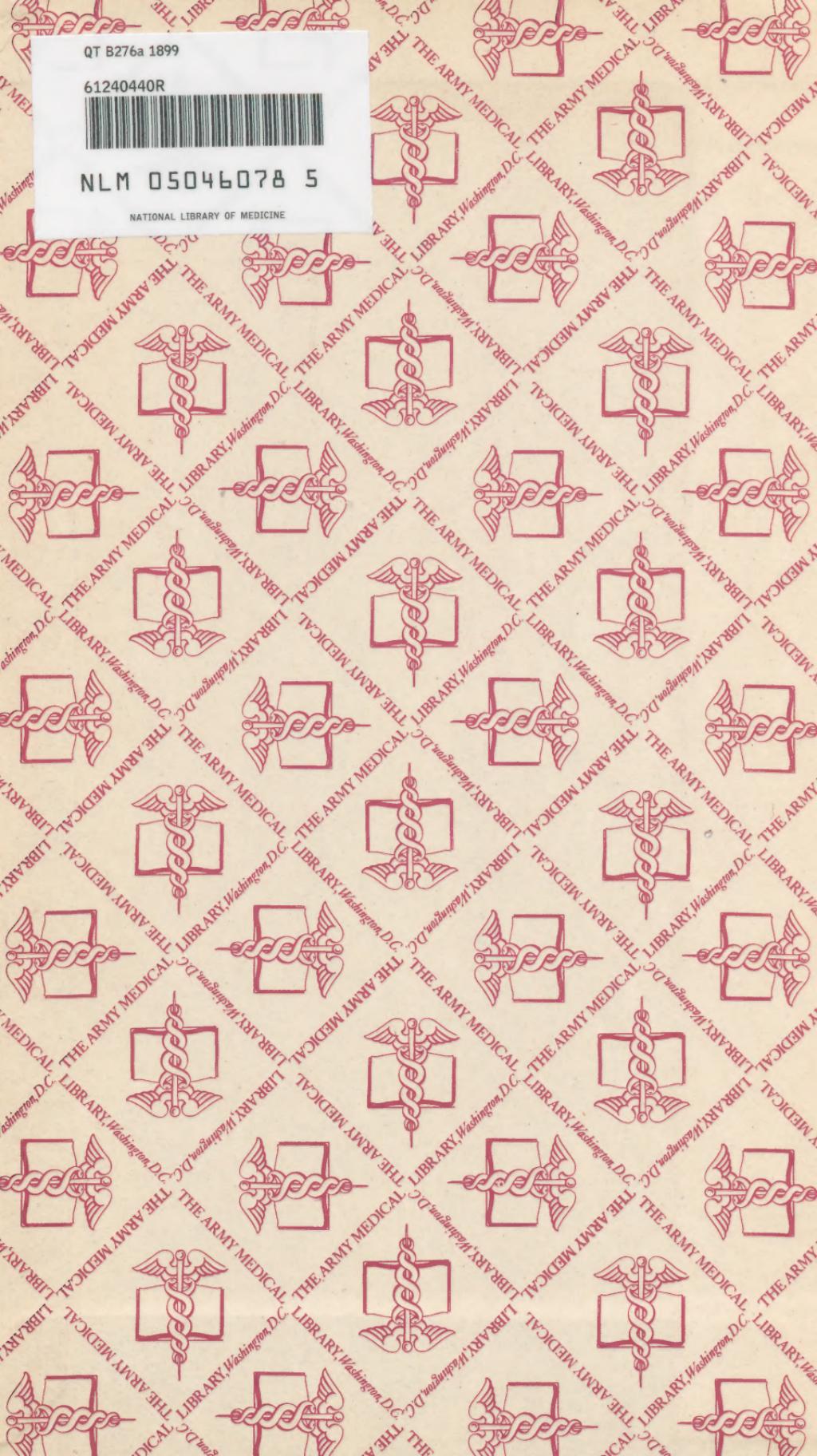
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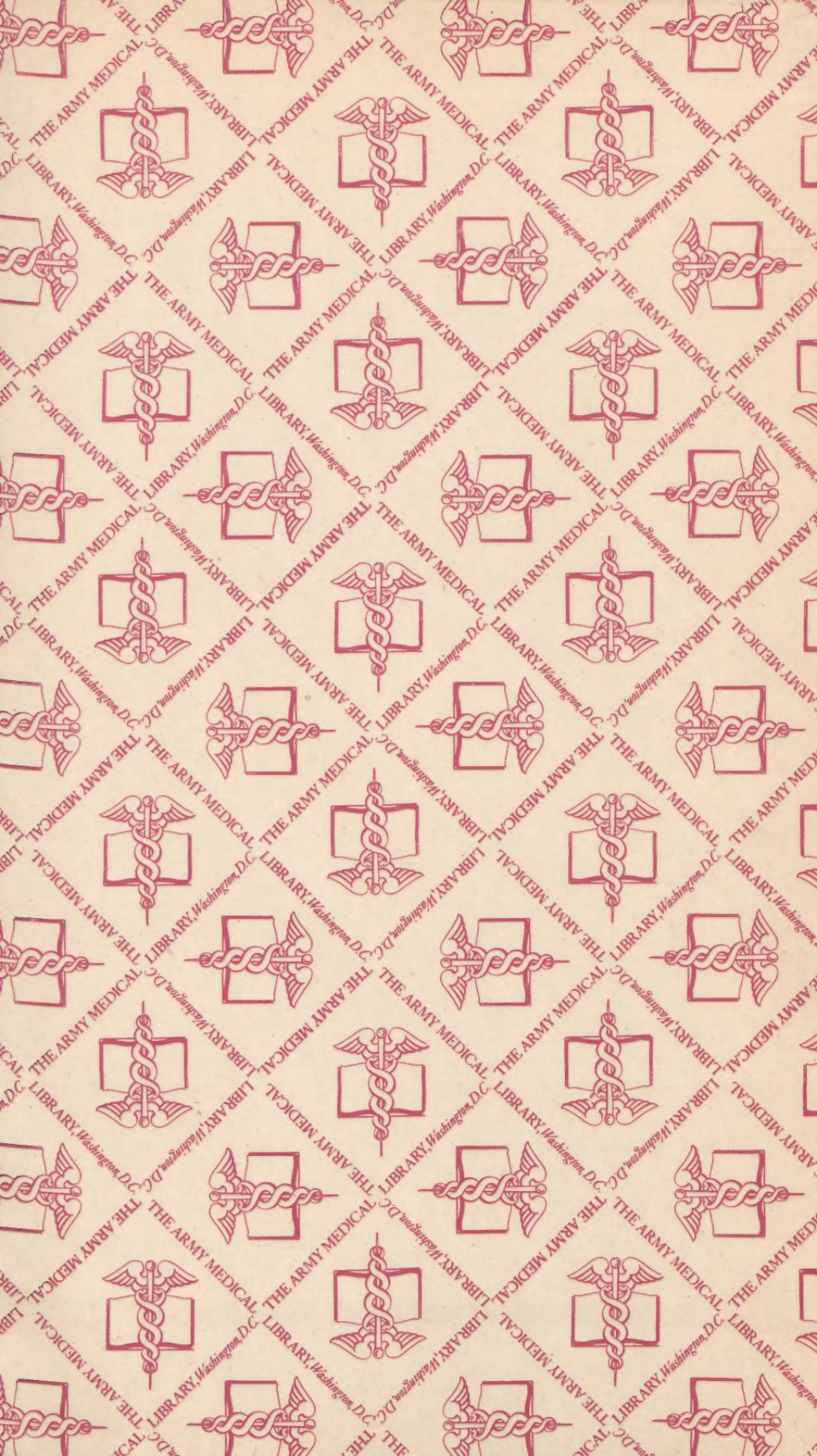
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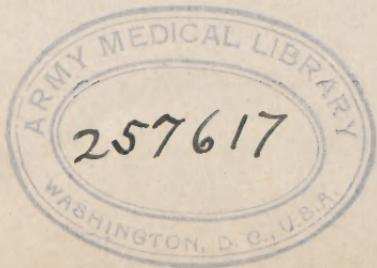
AN ABSTRACT  
OF  
**PHYSIOLOGY**  
FOR  
MEDICAL STUDENTS  
AND  
PRACTITIONERS.

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**University of Virginia.**

(SECOND EDITION.)

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## PREFACE TO THE SECOND EDITION.

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This little work was originally written to take the place of the usual students' notes in the course of lectures on medical physiology in this University. The great difficulty experienced by students, even good students, in following lectures when compelled to take notes, and the utter inability of others to take notes at all, was my only excuse for presenting in this abridged form the elementary principles of Medical Physiology.

From time to time there has been added to this work practical suggestions which pertain to therapeutics, practice, surgery, etc., with the result that the writer now believes it to be, as far as it goes, a practical physiology. The work presupposes a knowledge of chemistry, anatomy and histology, and is written primarily for the student, at the same time the writer has endeavored not to forget that the student of to-day is the practitioner of the morrow and to shape his instruction accordingly. To allow the student the exercise of his own powers, and to give him room for the insertion of such notes as a rapidly growing science demands, alternate pages are left blank.

My obligations to the standard text books of the day are palpable and are hereby acknowledged.

*University of Virginia,*

P. B. BARRINGER.

*October 1st, 1899.*





# Physiology.

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## CHAPTER I.

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**Physiology**, meaning literally, a "discourse on nature," is practically for the medical man a study of the *functions* or *actions* of the various organs and tissues that make up the living body, in contradistinction to the study of the *forms* and *structure* of these organs and tissues, as given in anatomy and histology. The appropriate work of each organ is here spoken of as its function. Hence we speak of physiology as the "science of the functions of life." Naturally the question arises, "what is life?" No satisfactory answer to this question can be given. All that we know is that, so long as there is a harmonious performance of the functions in organized bodies, we observe in them a series of continuous manifestations of activity, which from experience we recognize as peculiar to living things, and hence call these manifestations vital phenomena. When, however, there is serious disturbance or lack of harmony in the performance of certain of these functions, they all soon cease, never to begin again; and we call such bodies no longer living. In short, the harmonious performance of function is what we call life, and its antithesis, death. The more perfect the harmony of action the better the physiological state, *i. e.*, the health, of the individual; while serious lack of harmony soon gives rise to those perverted states of body condition to which we apply the terms ill health or disease, and which continued gives death.



From another standpoint, life may be described as "the adjustment of internal actions to meet changes in external conditions". This definition takes cognizance of the fact that life first appeared upon the earth in simple form, that it has been transmitted by inheritance through countless generations to all forms now found upon the earth, and that the status of any present living form in the scale of life is fixed by the capacity of its antecedents to meet the diurnal, seasonal, meteorological and other changes necessarily encountered. This means that man, the chief subject of our discussion, as he stands to-day, is physically, at least, the resultant of a series of progressive changes induced by varying environment. A very natural inquiry is "whence comes this simple initial life on earth?"

The experience of mankind is limited to the continuation of life from antecedent life. The most careful scientific investigation demonstrates the present impossibility of "spontaneous generation". The logical result of these facts is that life first appeared upon the earth as the result of some force more potent than any now known as acting in this field and under conditions which, as nature is now constituted, seem impossible. A good scientific name for such a force would be the OMNIPOTENT and for the act the Creation.

"Mathematics and dynamics fail us when we contemplate the earth fitted for life but lifeless and try to imagine the commencement of life upon it. This certainly did not take place from any action of chemistry or electricity or crystalline grouping of molecules under the influence of force, or by any possible kind of fortuitous concourse of atoms. We must pause face to face with the mystery and *miracle* of the creation of living creatures."

LORD KELVIN.



**The Evidences of Life**, briefly put, are as follows:

- (1.) *A peculiar chemical composition.*
- (2.) *Peculiar structural and physical properties.*
- (3.) *Activities during life. (Vital phenomena.)*

We find, however, that the above evidences of life are not peculiar to animal organisms, but are presented with almost equal force by vegetable forms. Before taking up the evidence of life in detail, we will note the relations between animal and vegetable life. While nothing could be more dissimilar than, for example, a horse and a tree, the two kingdoms which these represent gradually blend, until we reach a point at which it becomes impossible to determine to which kingdom a certain representative belongs. It has been proposed to establish an intermediate kingdom, to which all these doubtful forms shall be assigned; but so gradually do these forms merge one into the other, that this would be but the formation of two doubtful boundaries in place of one. There are, however, certain principles of differentiation that will enable us to compare the two forms of life in general terms, leaving detail to special works on the subject.

**Comparing animal and vegetable life**, we find that as regards the substances required for *nutrition*, animals require organic matter (primarily vegetable) while plants can subsist on inorganic matter alone, only the higher forms requiring organic food. There is moreover a great difference in the physical state of the foods used by the two types, the animal takes into its body cavity solid or semisolid matter, to be later dissolved by digestive processes, while plants use only foods in solution. As regards the gaseous elements of metabolism we find that animals take in O and give off CO<sub>2</sub>, while plants, at least in the sun-light, take in CO<sub>2</sub> and give off O. The complex organic pigment, *chlor-*



*rophyll*, is found in almost all plants; while its presence among animals is unknown except among the very lowest. As regards the supporting framework of animal bodies as compared with plants, we find that, in the one, it is usually central and composed chiefly of the carbonates and phosphates of the earthy bases; while in the latter, as a rule, it is more externally disposed, and consists of cellulose. Upon looking at the relative power possessed of forming complex chemical bodies, we find that plants under the influence of the sun's rays can form highly complex chemical substances, among others *albumin*; while animals are incapable of forming these complex bodies and must obtain them secondarily from plants, or, as in the case of carnivorous animals, indirectly from animals that are vegetable feeders. When we come to compare the progress in development, we find that animal life is far advanced beyond plant life, in that *it* shows the almost universal evidence of a digestive *system*, a nervous system, and a complex circulatory system. The first can hardly be said to exist in plants; while the two latter exist, if at all, in a very rudimentary form, (*Mimosa sensitiva*). Even the more advanced forms of plant life, in this line, (*Venus fly trap*, etc.) are far behind the simpler animal forms, having,—as a rule, the functions only of circulation, respiration, and digestion well developed. These functions hence are often called the "vegetative functions." The lack of symmetry in the disposition of the organs performing these so called vegetative functions among animals is striking, as compared with the beautiful bilateral symmetry of the nervous and muscular systems. Lastly, we see that, as regards their relative position as conservators or expenders of energy, they differ widely. Plants, from simple ele-



mentary bodies, or their binary forms, build up elaborate chemical substances of great potentiality; while the life history of animals requires that they receive and break down these bodies of complex molecular form into simpler types, with ceaseless evolution of energy. In other words, plants are accumulators, and animals dissipators of energy. Having seen wherein animal and plant life differ, we pass on to consider the evidences and manifestations of life in both forms.

**I. Chemical composition of living bodies.**—Only about fifteen of the seventy or more elements enter into the composition of living bodies. Of these elements four, viz. Carbon, Hydrogen, Oxygen, and Nitrogen form about 97 or 98 per cent of the total weight of such bodies. They are hence often called the "organic elements." You will observe that these four represent the extremes of physical condition, chemical affinity, chemical inertia, mobility, etc. Considered in detail we find, (1) *Carbon*, is a solid, allotropic, stable, and with chemical affinities almost nil, at ordinary temperatures, except in organic bodies. In organic bodies, however, we find this element to combine so freely and in such variety of form, that we often call organic chemistry the "chemistry of the carbon compounds." (2) *Hydrogen*, is the ideal gas, the perfect type of mobility. Its chemical union with O, outside the living body, is accompanied by the evolution of intense energy, as in the oxyhydrogen blowpipe. In the organism, its union is less free and less energetic. (3) *Oxygen* is also a gas, less mobile than the above, but infinitely more intense in its chemical affinities. A large part of the energies of the human race are directed toward the solution of the problems of properly starting, regulating, and controlling the chemical affinities of this element. The



flint and steel of olden days, and the lucifer of to-day, are as it were, but condiments to whet the appetite of this omniverous monster for the special food we wish him to use. (4) *Nitrogen*, again a gas, is the most indifferent of all in its chemical attachment. Even when united, its bonds of union are very unstable ; and it is this ease of separation from its attachments that makes it a component part of all explosives. These elements unite among themselves in all forms, binary, ternary, quarternary, and beyond even this, with addition of some secondary elements, usually Sulphur and Phosphorus. The latter element is particularly abundant in the class of nucleo-proteids. Not only do these elements form the bulk of our bodies, but their combinations furnish us all of our true foods. The binary forms give us  $H_2O$ , our water ; ternary forms  $C_6H_{10}O_5$  and  $C_6H_{12}O_6$ , our starches, sugars, and also  $(C_{21}H_{38}O_2)_3$ , our fats ; While the more elaborate composition,  $C_{50}H_8N_{18}O_{23}S.$ , furnishes our flesh. Give us but the salts, and we have our foods. Aside from the four elements above named, we have the following elementary bodies, as more or less constant constituents of living matter ; viz., calcium, phosphorus, sulphur, sodium, chlorine, fluorine, potassium, magnesium, iron, and silicon, in the order of their abundance.

**II. Structural properties of living bodies.**—All living bodies, from highest to lowest, are composed of *cells*. Even the highest and most complex organisms, including man, begin life as a single cell. Some, during their entire existence as perfect organisms, free and independent creatures, never reach a stage higher than a single cell. This group of unicellular organisms, called the *Protozoa*, is of great interest to the physiologist in that it shows how undifferentiated cells can perform all the functions necessary to a more or



less perfect life. The amoeba and its kind are the best examples for study. In the great majority of cases, however, by the multiplication of cells, and by the formation of cells especially adapted to the performance of certain functions, (differentiation,) the original unicellular type becomes a complex, highly differentiated living body, bearing little or no resemblance to the lower type, but differing in degree rather than in kind. The name Metazoa is applied to this group of multicellular forms; and it includes infinitely the greater number of living creatures with which we are familiar, including man. Turning from the cell as an organism to the cell as a basis of histological or tissue structure, we find it primarily to consist of "a mass of protoplasm enclosing one or more vesicular bodies called nuclei." It is this protoplasm, "the active principle of life," that gives rise to all those activities during life which we call "vital phenomena."

**The vital phenomena**, are (1) The power of *voluntary and reflex motion*, with all that this implies ; (2) the power of *nutrition* ; (3) the power of *reproduction* ; and (4) the power of passing in time through a series of changes in condition, which we call the *cycle of life*. These changes are birth, growth, developement, decline, and death.

As regards the first of these, *voluntary motion*, it is the most commonly observed manifestation of life. This even to the child, is a manifestation of life. At first thought one is not disposed to consider plant life as endowed with motion. But the tons of weight in a large tree have been raised above the earth against gravitation. More active, but less forcible, evidences of motion among plants are seen in the movements of the evening primrose, sensitive plant, etc. The simplest form of motion in animal life is seen in the amoeba.



The protoplasmic processes, or pseudopodia it throws out, are but the result of a contraction in one diameter and extension in another. The same changes taking place in each unit of the multitude of cells in the muscular tissues of higher forms, bring about a result, greater only in degree. The movement of the cilia, though less understood, is probably but an alternate action of the contractile elements of the opposite sides of the hair-like processes. In addition to the coarser phases of motion here referred to, which are due to the action of contractile tissues only, living bodies have other and more subtle evidences of energy in response to stimuli, as conduction, secretion, etc., embraced under this head.

Under the head of *nutrition* we usually recognize a series of most complex chemico-physical processes; the complexity of which however is in large measure dependent upon the wide differentiation of the cells set apart for this work. If we take one of the simpler forms of life, and study its functions, we will see it presenting only the essentials. In the amoeba, we see the organism live by a mere exposure of its surface to the oxygen of the medium around it; we see the flow or "streaming" of its protoplasmic body, by which this exposure is constantly renewed. We see it receive into its clear, jelly-like body, madder, gamboge or other foods fed to it, we see these slowly dissolve and disappear, and we cannot but perceive the utility of the streaming, as a means by which all parts are equally supplied with the nutriment obtained. Last but not least, we see it by a simple protoplasmic extension free itself of any undigested remains. In this we have an epitome of the complex nutritive functions, respiration and digestion with their mechanical auxiliary circulation; and also have a forecast of



that mystic series of phenomena, embraced under the head of metabolism.

The next of the vital phenomena, *reproduction*, (propagation) is that function, the consummation of which is the goal of individual existence. Simple in certain forms of animal and plant life, it is in others a most varied and elaborate process. The general plan of reproduction may be divided into two forms; viz. one, in which there is a division of an organism into two or more parts, which henceforth develop independently, but equally, the other,—the separation of a part which develops individually, from an older organism, which continues to exist, although but for a time. The former is the rule among the protozoa, the latter the rule among the metazoa. In the first form there is little or no differentiation into sexes, in the latter there is a differentiation into female and male forms. The former produces the germ cell or ovum, and the latter the sperm cell or spermatozoon, which is necessary for the fertilization of the ovum. As this differentiation into sexes proceeds, we have more or less evidence of sexual contact, preceding the reproductive process. When we reach the higher forms, the complex act of coitus forms an essential preliminary.

Of the *Cycle of Life*, we may say that all organisms, both plant and animal, when not interrupted by premature death, pass through all its phases. The first of these phases, *birth*, means but a separation from the parent organism, with the power of independent life. We thus see that life is obtained by inheritance. (*Omne vivum ex vivo.*) The next of these phases, *growth*, is the power of increasing in size and substance. We must be careful to differentiate between the true interstitial growth of an organism, embodying as it does the nutritive functions of digestion, absorp-



tion, etc., and the superficial growth of a crystal, which constantly encloses unchanged the crystal of yesterday in the larger crystal of to-day. While *development* is a constant accompaniment of growth, it differs in kind rather than in degree, and may be said to be that change in condition by which all living bodies become more capable of performing their respective functions, till maturity and "the prime of life," is reached. The next phase, *decline*, presents no sharp limit of differentiation either in time or functional activity, from the preceding phase. While up to maturity there is a constant (receding it is true) increment of gain in both frame and faculty, the turning points of these do not coincide. Nor do the different organs of the body coincide with each other. As the decline of the thymus begins in babyhood, and the decline of the eye in boyhood, and other organs at stated times before what we call maturity, we say that decline begins for an individual only when the general nutritive activities have diminished, until the output is greater than the income, the waste than the repair. From this time on, functional activities fail, decay and the special degenerations of old age (fatty and calcareous) begin, and we soon see the cessation of all functions, i. e. *death*. Exactly which function is the last to fail, varies with the cause of death. Usually it is the heart, but "death" occurs whenever either the brain, the heart or the lung, ceases to perform its function. If we note with great care, we may get an approximate idea of when death occurs, in so far at least as the cessation of the chief objective functions is concerned. This cessation of mechanical function we call *somatic death*, but there is a slow progressive loss of functional activity on the part of the tissues which we call *molecular death*, and to which we can assign no



time limit. Somatic death, (practical death,) could we but see the internal workings of the thoracic viscera, might be limited to a second ; but molecular death can not be so limited, for it is a gradual process, merging insensibly into that state, popularly known as decay. It is but the loss of functional activity by one tissue after another, till all cease and life truly ends.

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## CHAPTER II.

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### The Tissues.

In the study of *Histology* we learned the form, the size, the color, and other structural properties inherent to the cells, and their aggregations, the tissues. In the study of *Anatomy* we saw these cells and their resulting tissues grouped into symmetrical parts and organs, which were constant in their presence, and bore a definite relationship one to another. It is between these two realms that the physiologist finds one of his most profitable fields of labor. This lies in the study of the functional relations of one tissue to another, and of the tissues to the organs. This study of the minute detail of the organs is called "*microscopical anatomy*," because while still anatomy, the microscope is necessary to its elucidation. The physiologist however requires more than this, he must consider not only the relationship, but the development, the life history, the chemical composition, etc. Here we will take up first, the simpler relations of the tissues to each other—where they are found and where they are not; their physical, and later their chemical properties ; and finally their functional activities in detail.



While a knowledge of histology is presupposed the following simple classification is given for the advance light it throws on physiology and pathology. Forecasts of function must from time to time be made, as the nature of the subject demands.

#### EPITHELIAL TISSUES.

**Squamous epithelium.**—Of two kinds. (1) *Stratified*, found covering the general body surface and lining all open body-cavities. Preeminently protective. Our chief defense against *sepsis* either chemical or bacterial in character. (2) *Pavement or Simple*, found in the alveoli of the lung, in the capsule, neck and narrow loop (Henle's) of the tubule of the kidney, and in pigmented form, as the inner-most layer of the choroid. Protective.

**Columnar epithelium.**—Elongated vertically. Found lining the alimentary canal, from the cardiac end of the stomach to the anus. Protective and secretory.

**Spheroidal, glandular or cuboidal epithelium.**—Found in all glands, forming their active secretory part or parenchyma. Secretory. A gland, whatever its kind, always consists of a basement membrane on the inner face of which we find the glandular epithelium with a free face next the central lumen. Outside of this basement membrane is a plexus of blood vessels supplied by nerves. The secreting epithelium is also supplied by nerves.

**Transitional epithelium.**—Dissimilar multiple layers. Found lining the prostatic urethra, the bladder, the ureter and the pelvis of the kidney. The only tissue which can long withstand the irritating influence of urine. Protective.

**Ciliated epithelium.**—Found lining the respiratory tract, with its lachrymal canal and eustachian tube, the



tubes and tubules of the testicle, the fallopian tubes and upper part of the uterus, the cerebral ventricles and the canal of the cord during foetal life. Locomotive and protective.

#### ENDOTHELIAL TISSUES.

**Serous (synovial) endothelium.**—Found lining all closed body-cavities, both serous and synovial. Both secretory and protective in function. The pleural, mesenteric and sub-diaphragmatic endothelium, presents stomata. This tissue when inflamed tends to adhere and form an organic union with any similar surface with which it is in contact, giving peritoneal and pleuritic "adhesions," iritic synechiae, etc. This property is taken advantage of in abdominal surgery and in the treatment of varicocele.

**Vascular endothelium.**—Protective in function. Found lining the heart and all blood vessels. The seat of late syphilitic deposits. It presents no stomata.

#### SKELETAL TISSUES.

**Connective or fibrous tissues.**—In the order of their relative abundance and importance. (1) *Areolar tissue.* One of the most widespread of all tissues, but especially abundant in the subcutaneous, submucous, and subserous planes. A modified form of it is adipose tissue. When this loose open tissue is distended with excess of transudate the condition is called "oedema" and where general it is called "anasarca." (2) *White-fibrous tissue.* This may be arranged in bundles of parallel fibres, forming cords, as tendons, ligaments, etc., or in felted membranes, more or less open, that invest of all the organs of the body. The first form of this tissue (tendons, etc.) is the most frequent seat of rheumatic inflammation. (3) *Yellow-fibrous, or elastic tissue.* Found in the inner layers



of larger blood vessels, ligamentum nuchae, ligamentum subflava, the ligaments of the larynx, true vocal cords and certain layers of the trachea, the bronchi, and their prolongations. (4) *Retiform or adenoid tissue*, is found as the supporting framework of all adenoid bodies, lymph nodes, ductless glands, etc. Besides these, a special connective tissue (neuroglia) is found supporting the nerve cells, and another (mucous or gelatinous) the vitreous humor of the eye. The latter is also found as the jelly of the umbilical cord.

**Cartilaginous tissue.**—All are covered by perichondrium. (1) *Hyaline cartilage*, is the variety found encrusting the articular faces of the bones, and forming the costal, laryngeal, nasal and tracheal cartilages. (2) *White-fibro cartilage*, forms the intervertebral discs, interarticular pads, and the circumferential rings around the glenoid fossa and acetabulum. (3) *Yellow-elastic cartilage*, forms the epiglottis, the eustachian tube, the corniculae laryngis and the cartilages of the external ear.

**Bony tissue.**—(1) *Compact bone*, found chiefly in the shafts of the long bones, the medullary cavity of which contains the fatty yellow marrow, (fat embolism). (2) *Cancelled bone*, forms the framework of the flat, cubical and irregular bones, and the extremities of the long bones. The cavities of this form of bone are filled with the albuminous red marrow. Both the above are enveloped in periosteum. (3) The teeth are but modified forms of bone, and are composed of *enamel*, covering the crown, *crustæ petrosa* (bone) covering the neck and fangs, and *dentine* (ivory) forming the internal body substance.

#### CONTRACTILE TISSUES.

**Skeletal or striated muscle.**—This tissue forms nearly half of the body weight and varies in mass from



the "stapedius" to the "quadriceps extensor." It is always enveloped in fascia and supported by internal septa of fibrous tissue. Supplied chiefly by cerebro-spinal nerves. Quick acting and voluntary.

**Cardiac muscle.**—This variety is found only in the heart. Imperfect striation, the arrangement of its nuclei, and absence of sarcolemma, differentiate it from the other two forms of muscle. It is supplied by both sympathetic and cerebro-spinal nerve fibres (digitalis). Quick acting but involuntary.

**Visceral smooth, or non-striated muscle.**—This form of contractile tissue, while quite widespread, is nowhere in large mass, except in the uterus. It is found in the walls of the following organs; all the hollow viscera and their ducts, all blood vessels and lymphatics, the trachea and bronchi, and the cavities and ducts of the generative organs. It is also found in the skin, spleen and iris (ergot). It is supplied chiefly by sympathetic nerves. Slow acting and involuntary.

#### CONDUCTILE TISSUES.

**Nerve corpuscles.**—These can not be classed histologically, but functionally they may be grouped into three classes. (1) Those cortical cells which alone among cells have the power of *initiating nerve impulses*. They preside over all other cells and cell functions. (2) Those lower cerebral, medullary, spinal and ganglionic corpuscles, whose function is to *transfer and distribute impulses* received. They may be stimulated by peripheral (sensory) or central (motor) impulses; but in either case they receive, transfer and distribute all impulses to their proper channels, augmenting or inhibiting them, as the case may require. In their order from above down they can handle any stimuli, from those calling for the most elaborate and complex



movements, to those most simple. (3) Those corpuscles which, having no independent action, can only *transform* stimuli received. (a) Those peripheral terminal fibrils, end-bulbs, tactile corpuscles and special sense organs, which can transform physical stimuli into nerve (afferent) impulses. (b) Those deep seated muscle plates on skeletal muscle, or fibrillar terminals in visceral muscles or glands, which can transform nerve (efferent) impulses into other forms of functional activity, as contraction, secretion, etc.

**Nerve fibres.**—(1) Non-medullated or "grey" fibres. These supply chiefly the viscera and blood vessels. They are usually connected with the sympathetic nervous system. (2) Medullated or "white" fibres. These form the fibres of the cord and other parts of the cerebro-spinal nervous system. They supply chiefly the muscles.

#### THE FLUID TISSUES.

##### THE BLOOD.

In man, and in fact in all vertebrates, the blood is a fluid which when examined shows the following:

**Physical properties.**—In *color* it is a scarlet red, when rich in oxygen (arterial), and a purplish red when poor in oxygen (venous). The color is not in the fluid portion of the blood, but is in the corpuscles or floating elements. The *reaction* of blood is faintly alkaline and the *taste* is saltish. The *alkalinity* of the blood, which varies in its intensity but is never absent, is due to the presence of di-sodium phosphate and to a less extent to carbonate of soda. The *temperature* of the blood in the warmest part of its course, as in the liver, is about one degree above normal body temperature or, 99.6°F.; but in the extremities it is often as low as body temperature (98.6°F), or lower. Its *specific gravity* is about 1060, an average between the specific

*Blood taking  
Sputum & sputum*



gravity of the corpuscles (1075) and the fluid portion (1045).

**Histological characters.**—When examined with a microscope, blood is seen to consist of an immense number of disc-shaped cells or *corpuscles* floating in a clear fluid called the *plasma*, or liquor sanguinis. There are two principal forms of corpuscles, the red and the white, the former being several hundred times the more abundant. The *Red blood corpuscle* as found in man is a circular, bi-concave disc with rounded edges and a depressed center, about  $1\frac{1}{3500}$  of an inch in diameter and about one-fourth of this in thickness. When viewed by transmitted light, these corpuscles are a pale yellow, and are red only by reflected light. More closely examined, each shows a colorless, elastic, structureless frame-work or *stroma*, infiltrated with a red coloring matter, *haemoglobin*. In nearly all specimens of blood, we will see some corpuscles smaller than the above, paler and of variable shape; these are called *microcytes* or blood platelets. Various theories have been given to account for their presence. The influence of *reagents* on the red corpuscles is best noted in the case of the gases, as N. O., which colors it violet red; C. O., cherry red; and O., which in varying amounts, gives from scarlet to purple. Rouleaux may often be formed from the simple shedding of blood, and less often crenation or the formation of spines (Physostigmin.) Other agents as heat, static electricity, tannic acid, etc., also affect the corpuscle. The red blood corpuscles are *formed* during foetal life in the *vessels*, but in later *infant life* in the blood glands, as the liver, spleen, etc., and in adult life probably in the red marrow of the bones.

The destruction of the red corpuscles probably takes place in the spleen and liver. The great variation in

*nucleated Reds* *macro* *blasts*  
*macro*



their ratio to the white corpuscles in the splenic vein and artery points to this organ, while the formation of bile pigments from haemoglobin points to the liver or a connected viscus.

The *White (blood) corpuscles*, or leucocytes, differ from the red in that they are found, not only in the blood vessels, but in many other parts of the body also. As "wandering cells" we see them in the general interstitial lymph spaces, as "lymph corpuscles" in the spleen, lymph nodes, adenoid bodies, bone marrow, etc. ; and this for the simple reason that, as free migratory bodies, they pass through vessel walls (diapedesis) and other tissues at will. Hence the immense variation in the ratio between red and white corpuscles in the various parts of the vascular system. Closely resembling the primitive unicellular organism found in our ponds, etc., the "amoeba," and possessing the same free movements, we call these movements in the leucocyte, "amoeboid." They are evident in all its forms, and alone enable it to perform its multifarious functions. These corpuscles, when at rest, are globular bodies variable in size, but usually about 1-2500 of an inch in diameter. They can throw out prolongations of the body substance (pseudopodia) at will, and follow after by their internal "streaming" movements. In this way they can either move from place to place, or flowing around a foreign body enclose it for food or otherwise. (Phagocytosis.) Reagents affect them variously, acetic acid clearing up the perinuclear protoplasm and showing clearly the nucleus, while magenta, and other stains, have apparently an affinity for the nucleus alone. The great variety in the size and other peculiarities of these white corpuscles has led to an attempt at classification by their affinity for certain stains. The term *oxyphile (eosinophile)* is

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3. Transitional Form differs only, from (2) in reaching  
lession induration.

4. Advanced Form, smaller tumor (2) - deeply fibrosed nuclei  
(10-30%) irregular shape. mitophase abundant  
nucleoplasm granules - large spleen  
and bone marrow.

5. Chronic phase, visible heterophiles but granules  
(2-14%) are larger, more refractive, specific affinity  
for acid stains (Ehrlich, orcein hematoxylin)

applied to those staining most readily by acid stains, while *basophile* is reserved for those staining most readily with basic stains. The conditions necessary to free amoeboid movement are a suitable media and proper temperature. Very many disappear as soon as the blood is shed, and their component parts are probably concerned in the coagulation that follows. These white corpuscles are probably formed in the adenoid bodies and lymph glands.

*Comparative Histology* shows us that all mammals, except the Camelidae, have circular, non-nucleated, red corpuscles; while all birds, reptiles, amphibians, and fishes, except the Cyclostomata, have the same corpuscles, oval and nucleated. The medico-legal value of this is most important. The more active the functional life of the animal, as the smaller deer, the smaller the colored corpuscle, to give superficial area for carrying oxygen, while for the same reason the corpuscles of the sloth is large.

**The fluid and coagulating elements** of the blood are in the plasma, or liquor sanguinis, which forms 65 per cent of the blood weight. When the blood is shed, a part of the plasma previously fluid becomes solid by coagulation. This newly formed solid is elastic and contracts, entangling in its open meshes the corpuscles, both red and white. The solid formed is called *fibrin*, and the entangled mass it makes, a *clot*. As the fibrin of the clot still further contracts, it squeezes out a straw colored fluid, the unaltered portion of the plasma, called *serum*.

Upon further study of this substance we find that fibrin (Hamersten's theory) is composed of two factors, one a globulin called *fibrinogen*, and an extractive substance called the *fibrin ferment*. The first of these, *fibrinogen*, is the chief factor and forms the

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clot. formation of fibrin from fibronogen. breakdown of plasma fibrin fibrinolysis

Plasma -  $\alpha_2$  anti-trypsin - C1 esterase inhibitor -

under influence fibrin fibrinolysis

Plasma - fibrinolysis - Serum

coagulation + fibrin = clot

Plasma + Coagulation - serum + clot = Blood

Plasma 97% water 3% solutes

solutes 9% fat

water, proteins, sugars, lactose, urea

9-9.7% proteins 1% albumin albumin

2.5% globulins

Red Corpuscles 60% H<sub>2</sub>O 39.5% hemoglobin 9.5%

4.0% Salts & Liquefied materials 1.5%

Proteins, chlorides, 2.1

4. Salts, sulphates, 0.5, nitrates, 0.15

great mass of the fibrin. It is readily gotten from such serous exudates as pleuritic, pericardial and hydrocele fluid. There is another globulin, paraglobulin, always found in blood serum, which was long thought to play an active part in this process but it is now known to be a passive agent entirely. The *fibrin ferment*, so called, is not really a ferment, but is probably also a globulin; a cell globulin, derived from the breaking up of the white corpuscle or other cells when the blood is shed. It is the exciting cause of coagulation, for regardless of other factors, if it be absent, coagulation cannot take place. It also seems proven that calcium salts are necessary to the coagulation of blood and that it can be prevented by their withdrawal. The especial characters of the globulins will be given later.

*Coagulation is influenced* by the state of the white corpuscles, and of the tunica intima, or lining of the blood vessels, for when this is injured (cell globulin) coagulation begins. The presence in the blood of foreign bodies, oxygen in quantity; and heat, all favor coagulation, while cold, carbon dioxide, and above all venom globulin, check or prevent it. Haemophilia is an hereditary disease afflicting males, (but derived only through female lines,) in which a tendency to free bleeding from slight wounds exists. Persons so afflicted are popularly called "bleeders," and no doubt have blood of imperfect coagulating power (calcium chloride). A tendency to hemorrhage in purpura, scurvy and other diseases is also noted.

**The pigment of the colored corpuscle**, called *haemoglobin*, is a complex chemical substance of red color, crystallizing (rhombic system) more or less readily in all vertebrates. These crystals are obtained with some difficulty from human blood, but are readily gotten



from that of a rat or guinea pig. The haemoglobin in the corpuscle can be dissolved out of the stroma, in time, by the serum alone, but more readily by water and still more freely by a solution of bile salts. This is aided by freezing the blood. Aqueous solutions coagulate at about 64°C. While crystalline, haemoglobin is hardly diffusible, and is therefore practically colloidal. Either in solution or in a dry state haemoglobin ultimately decomposes into an amorphous blue-black pigment, *haematin*, and a colorless proteid, probably a globulin. The haematin carries the iron of the haemoglobin with it. A chloride of haematin, called *haemin*, is crystalline; and these crystals (Teichman's), which can be obtained from old blood spots, are of medico-legal value. When, however, the blood decomposes in a blood vessel or in the tissues, as in extravasations, haematin is not formed, but a crystalline, yellowish red body, *haematoidin*, seemingly identical with the bilirubin of the bile. The "old gold" of a "black eye," and the yellow of the corpus luteum, is due to this pigment. The most characteristic property of haemoglobin, however, is its power of uniting loosely with gases, notably with oxygen. In *vacuo* or away from O, it is haemoglobin, in arterial blood or wherever O is abundant, it is oxy-haemoglobin, and when long exposed to the air as in old blood stains, or in the crusts and scabs of bloody wounds, it is meth-haemoglobin. This tendency of the haemoglobin of the red corpuscle to unite with gases is not exhibited for O alone, but it is also shown for CO, CO<sub>2</sub>, etc. When CO is brought into contact with haemoglobin, a permanent union is made, so permanent in fact that the functional activities of the pigment are lost, while the haemoglobin union with CO<sub>2</sub> is but temporary and loose. Each of the foregoing haemoglo-

Uvula shows 2 absorption bands D + E.  
rest of spectrum being nonabsorbing.  
Diff. between 2 bands is D + E. (nonabsorbing bands  
definite).

bin compounds has its own definite spectrum, which is of much medico-legal value. **The gases of the blood**, when measured at standard barometric pressure and temperature, are found to equal about *60 volumes per cent*; that is, 100 cubic inches of blood, gives about 60 cubic inches of gas. This is made up of varying quantities of the gases O and CO<sub>2</sub>, and a definite and almost unvarying quantity N. The quantities of the two former gases vary markedly, only when taken from what, we will learn, are different kinds of blood, as in the table, thus:

100 Vol. of blood,	Vol. O.	Vol. CO <sub>2</sub> .	Vol. N.	To. Vol.
Arterial blood,	20	39	1	60
Venous blood,	10	49	1	60

The O and CO<sub>2</sub> differ markedly, however, in the ways by which they are held. The O is chiefly in *loose chemical combination* with the *haemoglobin* of the corpuscles (oxyhaemoglobin), only the "absorption" amount being in the fluids of the blood. The CO<sub>2</sub>, on the contrary, is *in loose chemical combination with both the corpuscles and the plasma*. In the plasma, the CO<sub>2</sub> is chiefly united in an imperfectly understood chemical union with the basic phosphates and carbonates of soda, while a small amount is simply absorbed. In the corpuscles a quantity of CO<sub>2</sub> is in extremely loose chemical union as above. When we place the blood in an air pump and exhaust, a vast difference in "chemical combination" is shown. Only the absorption amount of O comes off in accordance with the laws of absorption, the bulk of it coming off suddenly when a low pressure is reached. In the case of the CO<sub>2</sub>, all comes off in accordance with the law of absorption,—the "combined" as well as the absorbed. Nitrogen is always simply absorbed.



**The blood considered as a whole**, is seen to be the great "common carrier" of the body ; the gases, the heat, the food, the waste products, are all carried by this medium. As the food and fluids of nutrition vary, not only in amount, but in the times when taken, the quantity of the blood must vary, and that irregularly ; for the loss of fluids from the body through the skin and other channels is just as irregular as their taking in. Still by experiment we have learned that the average weight of the blood in the body is about 1-13 of the body weight. The method of obtaining this relative weight (Welkers) is as follows : From a canula in the carotid, draw, say 1 oz. of blood, which we will dilute with 499 ounces of water and set aside. Draw all the remaining blood from the body, wash the blood-vessels till clear, and then macerate the finely chopped body, keeping note of all the water used in these washings. The first blood drawn is used as a color-test solution (1 in 500), and water is added to the body blood and washings, the amount being noted, till the body blood solution, and test solution, agree in color. Three factors being known, we compute the fourth. In practice CO is passed through both solutions, to fix the haemoglobin in an unchangeable form. The distribution of the blood at any given time is about as follows :  $\frac{1}{4}$  in the liver ;  $\frac{1}{4}$  in the muscles ;  $\frac{1}{4}$  in the heart, lungs, and larger vessels ; and  $\frac{1}{4}$  in the skin and the remainder of the body.

**Abnormal conditions of the blood**, exist (1) by reason of variations in the proportions of the blood, and (2) in the presence of unusual organic constituents, and (3) in the presence of living organisms in the blood. Of the variations in relative proportion, an increase in the general mass of the blood is called *plethora*, while a decrease in the amount is *anaemia*. In addition to this



variation in mass, there is a variation in the ratio of red and white corpuscles, the former decreasing, the latter increasing, as in *leukaemia*. There is also a variation in the ratio of solids and fluids, an excess of the latter producing *hydraemia*. The conditions of unusual organic constituents are *mellitaemia* or sugar in the blood, *lipaemia* or fat in the blood, and *uraemia*, or urea in the blood. The living organisms which may be in the blood are, the *bacteria* in various forms, the *bilharzia haematobia*, the *plasmodium malaia*, etc.

#### THE LYMPH.

The *lymph* is that portion of the plasma which, having been dealt out to the tissues for their nutrition in excess, is returned unused to the general circulation, through the *lymphatics*. It is a colorless alkaline fluid containing leucocytes or lymph corpuscles. The normal organic constituents of lymph are much the same as those of plasma, but the proportions differ. The fibrin-factors are more feeble, and a lymph clot is soft and delicate. The lymphatics from the intestinal tract, during the digestion of fatty foods, bear great quantities of "fatty granules" in their lymph, giving them a milk-white color and their name, *lacteals*. This fat laden lymph is called *chyle*. A worm-like organism, the *filaria sanguinii*, is, in certain conditions, found in the lymph (elephantiasis).

also certain toxic sub. produced in metabolism  
coag spontaneously - plasma contains fibrinogen



## CHAPTER III.

## CHEMISTRY OF THE BODY.

In a general way we have already considered the chemical elements that make up the body, but rather as units, than aggregations. We must now approach the most complex and unstable of all known chemical substances, the higher organic compounds, sometimes called the *plasmata*. Some of these are so very unstable, that their simple removal from the body, or even disturbance in the body, will bring about changes, not only of chemical relation, but of physical condition. Such bodies as these, *viz.*: protoplasm, blood-plasma, muscle-plasma, haemoglobin, etc., we will probably never know the true composition of, even if they have a definite chemical composition. But somewhat lower in the scale we have bodies formed from the above, which, while still unstable, have a definite composition, and certain fixed physical properties always present, which justify us in classifying them together. These form one of our chief sources of food, in fact our most essential food, and we group them under the name of *proteids*.

**Proteids** are divided into several classes, but all are colloidal, laevogyrous, nitrogenous bodies, coagulable by certain reagents. They are the anhydrides of the peptones, and may be divided into the true proteids or *albumins*, and the false proteids or *albuminoids*.

(1) Under the head of the *albumins* are classed the true proteids having the general percentage composition given on page 16, and possessing the following general characters. They are all amorphous, all are

## I. Albumins

1. Sol. in H<sub>2</sub>O, ~~coag~~ by heat  
 2. Egg.  
 3. Serum. Protein reaction  
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2.000-4.000 C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>  
 2.000-4.000 C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>  
 2.000-4.000 C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>  
 2.000-4.000 C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>

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## II. Globulins

1. Blood H<sub>2</sub>O  
 2. Sol. in salt sol. ~~coag~~ by heat + strong acid  
 3. Egg. ~~coag~~  
Protein reaction  
 (1. General, 2. Paracolloid 3. Fibrinogen)  
 (4. Myo., 5. Proteins 6. Globins)

III

1. General albumins ~~neutral~~ ~~6.0-7.0~~ ~~W.M.~~  
 1. General ~~2. Sol. in salt sol.~~ ~~coag~~ by heat  
 2. Albumin sol. in ~~acid + alc. sols.~~  
 3. Not coag heat

IV

1. Blood H<sub>2</sub>O  
 2. Sol. in salt sol. + dilute acid  
 3. Coag. ~~in~~ ~~heat~~ H<sub>2</sub>O.

## V. Coag Proteins

1. General ~~coag~~ by heat + dilute acid  
 2. 2. Sol. H<sub>2</sub>O + saline  
 3. 3. Sol. H<sub>2</sub>O, dil. acids  
- dissolved different not strong acids

## VI. Chromogen Proteins, Intermediate

1. all sol. dil. H<sub>2</sub>O, some in H<sub>2</sub>O  
 2. Dissolve slightly in heat  
 3. Red color biuret test  
 4. Am. sleep prep.  
 5. not coag heat

## VII. Peptones

1. not coag heat  
 2. Sol. H<sub>2</sub>O, Saline, acids + alc. Am. Salt  
- dissolved in water potassium iodide  
 3. Dissolve give red color biuret test

## VIII. Proteins

1. Milk - curdles  
 2. Chondrin - curdles  
 3. Protein - curdles - heat - W.M.  
 4. Protein - curdles - heat  
 5. Elastin - curdles  
 6. Mucin - curdles - heat - W.M. of egg

changed by heat, and all when heated with strong nitric acid turn yellow, which in turn is changed to orange, if ammonia, caustic soda, etc., be added. The first group in this class are the *native albumins*, *viz.* : egg albumin, forming the white of egg, and serum albumin, found in blood serum, and forming the albumin of albuminuria, etc. The next group are the *derived albumins* (albuminates), *viz.* : acid albumin, alkali albumin, and perhaps casein. The two first are formed when acids or alkalies respectively are added to a native albumin. The latter is formed, when the protein constituents of milk are coagulated under the influence of rennet, etc. The third group includes the *globulins*, which, while bearing a general resemblance to the other albumins, are distinguished by being soluble in dilute saline solutions, and precipitated by strong saline solutions. They are : globulin, forming in an impure state the crystalline lens of the eye ; paraglobulin, one of the serum constituents ; fibrinogen, the chief of the fibrin factors ; myosin, the coagulating factor of muscle plasma ; vitellin, the protein constituent of the yellow of egg ; and globin, a constituent of the complex body haemoglobin. The fourth group includes the complex body *fibrin* alone. The next group, *coagulated albumin*, alone, which is formed by the influence of heat, nitric acid, alcohol, etc. (The *peptones*, while the hydrides of the albumins, can hardly be classed with them. They are formed from the albumins, in varying manners, which we will consider under digestion.)

(2) The *albuminoids* are nitrogenous, non-crystalline bodies, closely allied to the albumins in general chemical composition, but differing from them in many ways. While closely allied chemically to the true proteids, and giving the proteid reaction with nitric acid and ammonia,

acid + ammonia



they are not available as food stuffs to any practical extent. They are *mucin*, the characteristic component of mucus; *chondrin*, obtained by boiling cartilaginous tissues; *gelatin*, obtained in the same way from fibrous (white) tissues as tendons, ligaments, etc.; *keratin*, a constituent (rich in sulphur) of hair, nails, horn, epidermal scales, etc.; *elastin*, obtained by boiling yellow elastic tissue; and *nuclein*, a constituent of the nuclei of pus corpuscles, and of the yolk of egg.

**Carbohydrates** are organic compounds containing C, H, and O; but the ratio between the H and the O is like that in  $H_2O$ , two atoms of H, to one of O. The members of this class which we will consider in the human body are but four. They are *maltose* ( $C_{12}H_{22}O_{11}$ ) the end product of starch digestion and forming the largest part of our food; milk sugar or *lactose*, ( $C_{12}H_{22}O_{11} + H_2O$ ) which occurs in milk, and is characteristic of this secretion; and *inosit*, ( $C_6H_{12}O_6 + 2H_2O$ ) or muscle sugar, a rare substance found but sparingly in the human body in health, and not in great abundance in disease (Bright's disease). Lastly, we have the all important *glycogen* ( $C_6H_{10}O_5$ ), formed in the liver by the action of the liver ferment on maltose. When not so converted, the maltose enters at once into the circulation, to be eliminated in the urine, giving diabetes mellitus.

**The neutral fats**, improperly called hydrocarbons, also contain only C, H, and O, but the ratio is not like that above, the C and H being vastly in excess of the O. This disproportion necessarily renders them readily combustible and great heat producers. They are neutral bodies (ethers), formed by the union of glycerin with the radicles of the acetic and oleic acid series. *Olein*, ( $C_{21}H_{38}O_6$ ) a fluid fat or oil at almost all temperatures, is formed by the union of glycerin ( $C_3H_8O_3$ ), with

Fructose (dextrin) glucose sucrose

Galactose Glucosamine Glucosaminic acid

Disaccharides  
(Sugars)  
 $C_6H_{12}O_6$

Sorbose PHYSIOLOGY

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Disaccharides  
Sugars  
 $C_12H_{22}O_{11}$

{ Sucrose (Cochlearine, cane sugar)  
Galactose (milk sugar)  
Maltose (malt)

1. CRYSTALLIZING  
Raffinose - lactose

2. COLLOID

1. Cellulose

2. starch - dextrin - polarizing to R.

3. Trehalose .. ..

4. Glycogen .. ..

5. Ribose - Guan

6. - D-Glucose (6-Hydroxy-3-

7. D-Glucosamine (2-Amino-2,3-

8. D-Glucosaminic acid

the oleic acid radicle ( $C_{18}H_{30}O_2$ ), giving the formula above. *Palmatin* ( $C_{18}H_{40}O_5$ ) is a solid fat at ordinary temperatures, hence it forms suet, tallow, etc., rather than the oily fats. *Stearin* ( $C_{21}H_{40}O_6$ ) is still more solid, and the very firm consistence of any tallow or suet depends upon its presence. The two latter fats are formed by the union of glycerin and the palmitic and stearic acid radicles respectively. Both these acids are of the acetic acid series. The alkalies readily displace the glycerin from its union with all of these acids, forming soaps, soft if potash be used and hard if soda.

**Temporary or intermediate products**, of various kinds, will be seen in the course of our studies of digestion, etc., but while all essential to this and other functions, they are in no sense foods. They are formed for some useful purpose, but do not remain long in their original shape, being broken up into other compounds, changed, reabsorbed or eliminated. They are quite numerous, but we will only take up the chief members. United with the base soda, two acids exist in the bile forming *bile salts*. These are *glycocholic* ( $C_{26}H_{43}NO_6$ ) and *taurocholic* ( $C_{25}H_{45}NO_7S$ ) acids. The former is the more abundant in the bile of man and the herbivora; while the latter, though found in human bile, is chiefly abundant among the carnivora. Both of these acids on boiling split up into cholic acid, and glycine and taurin respectively. *The bile pigments* are also two in number. Of these, an orange red pigment called *bilirubin* ( $C_{16}H_{18}N_2O_3$ ) predominates in man and the carnivora, while *biliverdin* ( $C_{16}H_{20}N_2O_5$ ) a dark-green oxidized form of the above, is found chiefly in the bile of the herbivora. It is believed that both of the above, as well as the pigments of the urine (urobilin) and of faeces (stercobilin), are derived from the pigment of



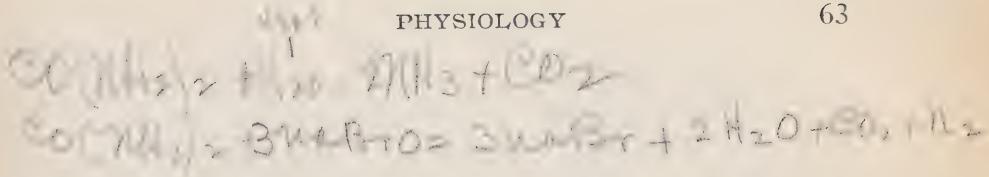
the blood, haemoglobin. *Cholesterin*, ( $C_{26}H_{44}O$ ) a crystalline, monatomic alcohol, found sparingly in a free state in the body, is abundant only in pathological fluids, cysts, etc. It is eliminated through the bile. It forms the chief constituent of gall-stones, and also of the floating crystals which sometimes occur in the vitreous humor of the eye. Other less important bodies, as lecithin, neurin, protagon, etc., are found but can not be considered here.

**Effete or waste products.** We will hereafter learn that the bulk of the foods used in the body (starches, sugars, and fats) are, after their combustion, eliminated as simple  $H_2O$  from the lungs, skin, and urine, and as  $CO_2$  from the lungs. The class of nitrogenous foods which we call proteids give us, however, waste products in the urine, which are primarily much more complex. *Urea*,  $CO(NH_2)_2$ , the most abundant, as well as the most important, of these representatives of the tissue waste, is found only in the urine of the mammalia. It is chemically a diamide of  $CO_2$ ; and, if in solution, will, in the presence of certain septic agencies, become hydrated, and form carbonate of ammonia, thus:



It will be seen that this salt is readily decomposed into  $NH_3$ ,  $H_2O$  and  $CO_2$ . Observe the chemical simplicity of our waste products as compared with our foodstuffs.

*Uric Acid* ( $C_5H_4N_4O_3$ ), found in large quantities in the excrement of birds and reptiles, is found only in a small and variable amount in the urine of man. In certain pathological processes, as in gout, it is deposited permanently in the tissues; and again, when in too great excess in the urine, it is precipitated, giving the so-called "gravel," and even "calculi." In a free state it



is quite insoluble, especially in cold fluids ; its salts are more soluble, its lithium salts being especially so. The cause of the deposits of "urates" in the fingers, toes and ears of gouty subjects is due to the fact that absorbed to saturation in the warm blood of the liver these urates crystallize out of their solutions when the blood is by exposure cooled down in the superficial parts named. *Hippuric Acid*, ( $C_9H_9NO_3$ ) exists in man's urine in about the same quantity as uric acid, but is abundant in the urine of herbivora. It appears to be formed from benzoic acid or allied substances. Benzoic acid administered by the mouth is eliminated in the urine as hippuric acid, thus rendering the urine more acid. As all the benzoic acid is not so changed, some appearing as free acid or benzoates we find this agent of great value in cystitis, ammoniacal decomposition, etc. The extractives *kreatin* and *kreatinin* form the basis of most *modern* "meat extracts". They have the unfortunate property of slowing the heart when given in quantity.



## CHAPTER IV.

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CIRCULATION.

By the term, **the circulation of the blood**, is meant the passage of this fluid from the heart to all parts of the body, through special vessels called arteries, and its return again to the heart by other vessels, called veins. Between the part we call an artery and the one we call a vein, we have a system of minute vessels, called capillaries, infinite in number and permeating every part of the tissues. The *cause of the circulation* is a difference in pressure on the blood in different parts of the vascular system, the heart producing the pressure. William Harvey demonstrated the complete circulation of the blood during the years 1616–1619, a curious mixture of truth and fallacy having existed previous to this time. Harvey was the first to show that there was, in reality, a *double circulation*, and two pumps; the right heart pumping blood to the lung, from whence it returned to the left heart, (*pulmonary circulation*); and the left heart pumping it to all parts of the general system, (*systemic circulation*), whence it now returned to the right heart, to begin its course anew. The so called “*portal circulation*” was demonstrated much later.

**The circulatory apparatus**, consists of a *heart*, having right and left auricles and ventricles, with their walls, septa and valves, investing membranes, etc., and a connecting system of *blood vessels*, the anatomy of all of which the student is here expected to review. The study of the **structure of the auricle** in man, shows that its thin wall is made up of two sets of cardiac



muscle fibres, a longitudinal and a circular or transverse. The longitudinal fibres run irregularly from the openings of the veins above, down to the auriculo-ventricular septum, and some are prolonged on the auricular face of the valves of the septum. The circular or outer fibers run around each auricle separately, (through the septum,) and around both continuously, more or less parallel to the auriculo-ventricular groove. From this line they continue up to the base of the heart, and there these circular fibres of cardiac muscle are continued on upon the veins entering the auricles, for, in some cases, an inch or more. This is most marked on the pulmonary veins, is somewhat less on the superior vena-cava, and is least on the inferior. These partly extra-auricular cardiac fibres, on the right side, are the last to stop their rhythmical contractions on the death of the heart, (ultimum moriens,) and the normal contraction wave of the heart seems to begin here. (Remak's ganglion.)

The **structure of the ventricle** is more complex. From without in we have some seven layers of cardiac muscle fibres. The most external layer, leaving the fibrous auriculo-ventricular ring, runs downward to the apex, turns in, enters the heart and becomes the inner or let us say seventh layer. Some of these fibres form the papillary muscles. The second, or next most external, running more obliquely to the apex, turns in and forms the sixth. The third, still more oblique, forms say the fifth; while the fourth is an almost circular (or transverse) layer of fibres.

The **structure of the fibrous-framework** of the heart shows first the dense fibrous auriculo-ventricular septum, pierced by two large openings. From the margins of these openings are continued inward the segmented fibrous sheets, which form the basis of the



valves. This septum, separates absolutely the muscular fibres of the auricle and ventricle. It seems moreover to be unpierced by nerves or vessels.

The *pericardium* of the heart, covering it from the apex to the large vessels at its base, is here reflected back from these vessels, to inclose it again. It consists of a layer of serous endothelium, upon a fibrous membrane, which is continuous with the connective tissue framework of the heart muscle; for while cardiac muscle is without sarcolemma, it is divided into fasciculi by planes of perimysium. The pericardial endothelium is on the outer surface of the heart and the reflexion brings it to the inner surface of the sac, hence endothelial faces are in contact. The *endocardium* lines the cavity of the heart, and is prolonged as the so-called "intima" into the blood vessels. It is of vascular endothelium, on a membrane of mixed fibrous and elastic elements, the latter most abundant in the auricle, and the former continuous through the cardiac perimysium with the pericardium. The **valves of the heart** are but reflections of the endocardium on a fibrous membranous frame-work. Observe the ring-like bases from which the auriculo-ventricular valves spring; and the semi-lunar valves with a similar setting, formed from the fibrous elements of the artery wall. Note that the auricular face of the mitral and tricuspid valves bears both muscular and elastic elements, while the other face, less equipped, is the anchorage of the tendons of the papillary muscles. The *lymphatics* of the heart are found in two sets. One of these is subendothelial, being found under both peri- and endo-cardium. The other, a deeper set, is found between the layers of muscular fibres in the heart wall. The *blood vessels* of the heart are pecu-



liar in their relative abundance, and correspond to its relative energy. The arteries of the heart are peculiarly thick, being especially rich in elastic elements, while the veins are unusually well supplied with valves. The **nerves of the heart** consist of extrinsic and intrinsic ganglia, and the fibres that unite the various parts. The *extrinsic* ganglia of control are probably located in the floor of the fourth ventricle of the medulla, (cardio-motor centre) and in the three cervical sympathetic ganglia. The *intrinsic* cardiac ganglia, usually superficial, are quite widely scattered, but among them we may note three distinct ganglionic masses. The first of these, located in the upper back part of the right auricle (*sinus venosus*), is called *Remak's* ganglion. The second is located in the interauricular septum and is called *Ludwig's* (*Bezold's*) ganglion. The third mass, located in the auriculo-ventricular groove, is called *Bidder's* ganglion. Terminal corpuscles (pressure sense) are found under the endo-cardium, and probably send afferent impulses. The *nerve fibres* supplying the heart, while quite complex, can be traced to at least two distinct sources, one to the cardiac branches of the vagus or tenth cranial nerve (inhibitor), and the other to the cardiac branches of the cervical sympathetics (accelerator) above mentioned. Other fibres, of unknown function, supply the heart.

**The structure of blood vessels** varies with the vessel, or part of the vessel, we select. The *artery*, or standard vessel, consists of three coats ; viz., the *intima* or internal coat, the *media* or middle coat, and the *adventitia* or external coat. The *intima* in detail is seen to consist of an internal layer of vascular endothelium, a subendothelial layer of connective tissue, and last a



layer of elastic fibres more or less open. This last layer is thickest in the larger arteries and thinner in the smaller ones, while it is practically absent in the veins and capillaries. The *media* or middle coat consists of a mixed layer of smooth muscular fibres and elastic tissue, which varies as follows. In the larger arteries we have chiefly elastic fibres, in the smaller arteries and "arterioles" chiefly muscular fibres circularly arranged. The veins are again relatively deficient in this coat, while as before it is wanting in the capillaries. The *adventitia* or outer layer consists of a felted network of white fibrous and areolar tissue, and in the smaller arteries a few elastic fibres are also found. This coat is best developed in the veins and is of course absent in the capillaries. In both the intima and adventitia scattered muscular fibres are often found, and these fibres often run in a longitudinal direction. The *capillaries*, we have seen consist merely of endothelium, with an areolar support behind it. The *veins*, strong in their outer coverings, are weak internally. They are usually provided with *valves*, which are mere folds of endothelium on a connective tissue flap, having elastic fibres on the inner or convex side. Nerve fibres supply the blood vessels, (vasomotor nerves) chiefly the smaller arteries, and end in the non-striated muscular fibres of the middle coat.

The **mechanism of the heart's action** consists in a contraction of its fibres in such order as to force the blood from the auricles into the ventricles, and then by a contraction of its ventricles to send it into the aorta or pulmonary artery as the case may be. *The movement of contraction begins in the circular cardiac fibres on the trunks of the large veins entering the heart, and the impulse imparted to their contained*

*Cork muscle - 1*



blood, and the narrowing of the openings of these vessels, overcomes the necessity for valves here. The wave of contraction extending on down the auricle reaches the fibrous auriculo-ventricular plate, and in a manner not understood is continued to the muscular fibres of the ventricle. As the fibres of the auricle complete their contraction (the blood being discharged into the ventricle), those longitudinal fibres that run out on the valves draw them back into the auriculo-ventricular opening, being aided in this by the elastic fibres. Now as the fibres of the ventricle act from above down, the back pressure of the blood completes the closure of these valves, which the tendinous cords of the papillary muscles limit. These muscles acting last, as we see they must, draw upon the valves and change a hitherto passive into an active source of compression. The contained blood of the ventricle is forced out into the artery, and as the ventricle relaxes its force, the backward rush of the blood closes against it the semilunar valves and prevents its return. The contraction of the auricles in their order, and of the ventricles, is synchronous, this synchronous action being intended not only to relieve the strain on a relatively weak septum, but to enable the heart to use all of its fibres.

The writer believes that much of the functional cardiac trouble reported is ventricular-arythmia. Cases are often seen in which the *heart* beats greatly exceed the *pulse* beats, being sometimes double the number. This alone can explain this condition. It is most marked with the nocturnal palpitations. (cactus)

**The cardiac cycle**, or time required in the heart's movement, is in the adult about .8 of a second for each beat. If we analyze this we find that it may be divided as follows :



Auricular contraction. (systole)	.1 second
Ventricular contraction. (systole)	.3 "
A period of cardiac rest. (diastole)	.4 "
Total	.8

This rate of action gives us, for man, about 70 or 75 beats per minute. In the new born child it is about double this, while with other children the rate is in accordance with age. The change in rate may be made either by varying the time of systole, or of diastole, but usually it is the latter. (digitalis, etc.)

**The heart sounds** may be divided into two parts, the first sound long and low, while the second is short and sharp. After the second sound is a pause nearly as long as the two sounds conjoined. (There is found upon analysis to be a short pause after the first sound, but it can not be differentiated by the ear.) The cause of the *first sound* is quite complex, but the chief elements in its production are the vibration of the auriculo-ventricular valves and the ~~chordae~~ tendinae, the contraction of the heart muscle, and the ~~rush~~ of the blood. The *second sound*, short and sharp, is due to the vibration produced by the sudden closure of the semilunar valves.

**The impulse** of the heart against the chest wall varies with the force of the heart, and with the amount of intervening lung, fat, etc., between the heart and chest wall. It is greatest during the excitement of the heart, and greater in the hypertrophied than in the normal heart, is more pronounced in the thin than in the fleshy, and in a state of expiration than in inspiration. The cause of the impulse is the sudden tension of the heart muscle. (cardiograph.)

**The arterial pulse**, due to the intermittent waves of the blood in the arteries, is our practical guage of the



heart's action. When the ventricle discharges its blood forcibly into the aorta, for instance ; while the bulk of the energy is expended in dilating the vessel, some is used in producing a wave of vibration which travels along the surface of the column of blood in the vessel, just as a wave travels along the surface of the water in a stream. This vibratory wave travels infinitely more rapidly than the blood-current (20 to 1), and it is this impulse wave that we feel under our fingers as the "pulse." The dilation of the aorta, mentioned above, puts upon the stretch all of its elastic elements, and when the ventricle begins to dilate at the end of its systole, the rush of the blood back into the heart is eager. The sudden closure of the semi-lunar valves checks this rush ; and the blood striking their arterial faces, recoils and produces a second wave of vibration which travels after the first, at a distance from it proportionate to the tension of the arterial wall, ~~the~~ quick action of the valves, etc. This wave is called the *dicrotic* wave.

We may substitute for the finger on the pulse a mechanical device known as a *sphygmograph*, which will record on a moving surface the various phases of a pulse wave, and we will find these phases as follows. As the wave passes under the button, representing the finger, we have a quick, nearly vertical upstroke of the recording needle until it reaches the apex, then a gradual decline which is broken about the middle of the decline by a slight rise from the dicrotic wave, then a continued fall to the end and repeat. If many tracings are taken we will note the great variation in the location of the dicrotic notch ; and we will learn that when the vessels are full and intra-arterial pressure is high, then it is well up near the top, but when intra-arterial pressure is feeble it is lower down. This variation in the

1. Mammalian respiration - section - 2

2. Respiration of the negative

3. Aspiration of heat negative

4. Choice of breathing methods

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place of the dicrotic wave can be understood from what has gone before ; a full artery and high pressure causing a quick recoil wave from the valves and vice versa.

**Intra arterial pressure** must always vary within quite narrow limits, if health is to be maintained, and yet the disturbing influences are so numerous that its regulation becomes one of the most complex of physiological problems. When an artery subdivides, the area of the cross-section (capacity) of the resulting branches is greater than that of the parent stem, and as the vessel continues to divide, this increase in relative area also continues. The result is, that we find that the aggregate sectional area of the capillaries is several (5-7) hundred times as great as that of the aorta. This is necessary in order that the capillaries may supply every part of the body, even the most remote, with blood. The outcome of this is, that the capillary system is as it were a lake in the blood stream ; and each single element of this system being in very elastic walls can dilate, and a dilation but little beyond the normal for each one will give a total increase in capillary volume that will drain the larger vessels dry. For its protection the arterial system must regulate the flow of blood into the capillaries and prevent any over-distention that will produce evil. The active factor in regulating this outflow is the small artery called the "*arteriole*," whose lumen is controlled by the large supply of muscular fibres in its wall ; these muscle fibres being in their turn under nervous control (vaso-motor).

The *physical factors* necessary for the maintenance of the arterial blood-pressure, we can readily see, are but four, viz.: (1) the strength of the heart beat, (2) the perfect working and coaptation of the cardiac valves, (3) the elastic resiliency of the arteries, and (4) the resistance offered to the outflow by the contraction of the arteriole.

Capillary 2-5 mm in length, 10-15 microns in diameter

Arterial 10-15 mm

Arteriole pressure 100-200 mm Hg  
Capillary 10-15 mm Hg

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Abdominal Constrictor increases blood pressure - by teleotaxis + small arterioles & arterioles of peristalsis on muscular tissue + nerve activity

Infranotal reflex increases blood pressure, by constricting arterioles thru muscular action

The working of the cardiac valves and the elasticity of the arteries being in health fixed factors, we have left as factors for varying blood pressure only the *variations in the strength and rapidity of the heart beat*, and the *variations in the lumen of the arteriole*. The varying combinations of harmonious action and intensity on the part of these factors give us any degree of pressure, with also equal variations in speed of current. For instance, a slow weak heart and narrow lumen gives medium pressure and a slow current, while a strong rapid heart and open lumen gives the same pressure and a rapid current. Or, if we take pressure alone, a strong, rapid heart and a narrow outlet gives the highest possible pressure ; and a slow, weak heart and open vessel, the lowest.

The heart and the arteriole being widely separated can not work in harmony without some means of communication or without, what is better, the regulation of a dominating centre which takes cognizance of blood pressure. Such a centre exists in the medulla and is called the *vaso-motor centre*.

The *vaso-motor centre* lying just above the calamus scriptorius, in the floor of the fourth ventricle, is kept informed, through nerve fibres, of the state of the blood pressure in the heart, and through other communicating nerves, called *vaso-motor nerves*, regulates the action of the muscular fibres in the arterial walls and thus the lumen. This centre may be influenced in three ways, *centrally, directly and reflexly*.

(1) Central influences as shame, terror, etc., disturb it, giving as a result, blushing, pallor, etc. Shock, which is a profound disturbance of the *central nervous system*, through whatever cause, is chiefly manifested through disturbance of this *vaso-motor centre* : the intense lumen-constricting impulses sent out giving pallor, cold clammy skin, etc.



(2) Directly, it may be influenced by the amount and quality of the gases in the blood, or by drugs in the blood, etc. The presence of  $\text{CO}_2$  in excess is a powerful stimulant to the centre, while  $\text{O}_2$  in excess diminishes its excitability. With drugs, strychnine stimulates, and opium, in a less degree, depresses.

(3) Reflexly, it is influenced chiefly by impulses from the heart, where from terminals under the endocardium (pressure sense) fibres pass up, through the so called Cyon's nerve, to join a (superior cardiac) branch of the vagus and thence to the centre. The impulses received in this manner are usually notifications that blood pressure is too high in the heart, but it may be the reverse. When uninfluenced from without, the *vaso-motor centre* seems to be in a *moderate state of tonic excitement*, sending out *vaso-constrictor* impulses at all times. When so needed, these impulses may be diminished or even absolutely inhibited, such action allowing dilation of the vessels: and the impulses, (or lack of impulses), producing this are called *vaso-dilator* or better *vaso-inhibitor*. In the centres of the lower spinal cord and perhaps in the sympathetic ganglia, some powers of local vaso-motor control seem to exist. The route of the vaso-motor nerves from the centre to the muscles of the blood vessels is as follows: Down the cervical cord to the level of the second dorsal nerve, where they begin to leave the cord by the rami-communicantes of the anterior roots, and they continue to come off down to the second lumbar nerve inclusive. After leaving the spinal cord, they join their respective sympathetic ganglia and proceed from here to the arteries through the nerves of the sympathetic system, those for the upper extremities and head, up, through the cervical sympathetics, and those for the lower limbs, down. In addition to the im-

<u>Spinal sympathetic</u> - vaso-constrictor for skin, heart, etc.	
Car. Constrictor action - vaso-constrictor for skin, salivary gland, heart, etc.	
Myelogenous, sympathetic.	Constricting the membrane of
<u>Trigeminal</u> , vaso-constrictor for eye, orbita, nose, etc.	
<u>Spinal Branch</u> - vaso-constrictor for tongue	87
<u>Splanchnic</u> , vaso-constrictor for abdominal organs.	
	skin, etc.
<u>Chorda tympani</u> - vaso dilator (1. submandibular, glands, etc.)	
	Secretory (2. Sublingual, glands, etc.)
<u>Neur. vagus</u> , vaso dilator	
<u>Neur. pudendus</u> , vaso constrictor	

Myelomatous - from 4-5 mm above point of calamus  
descentius to 1-2 mm of corpora quadrigemina  
Distalities appear below point of lowest 2 thoracic nerves  
= dilatation rectal muscle  
Thus of inferior hypogastric nerve = dilation of uterus  
Myelomatous act.

pulses sent out through the vaso-motor nerves for controlling the tone of the arteries, the vaso-motor centre sends out tonic impulses for the *regulation of the heart*. Those impulses for slowing and weakening the heart, called *inhibitory impulses*, go through the *vagus*, or tenth cranial; while those for quickening and strengthening, called *acceleratory impulses*, go through the fibres of the cervical *sympathetic*, both these nerves joining the intrinsic cardiac ganglia. Thus we see that the controlling centre may quicken or slow the heart, may dilate or narrow the lumen of the vessel, or may use any combination of these. The need of a centre is seen, however, when we know that the heart's action must need vary with the emotions, with variations in temperature, with muscular exercise, age, sex, posture, etc., etc.

**The normal pressure in the different vessels** may be approximately determined, despite the variations in the tone of the vaso-motor centre and other disturbing influences. Trying a canula in some large artery and connecting with a U tube, we see the blood rise to quite a height in the limb of the tube, and fluctuate with the heart beat. We can get the mean height of our blood column by averaging the extremes of fluctuation; but the column of blood tends to coagulate, and is moreover unwieldy, so it is better to use a column of mercury. This mercury may moreover be made to carry a registering float (manometer), and give us a graphic record of the arterial variation. We find a normal pressure in the aorta of about three pounds to the square inch, in the brachial artery of over two pounds, in the capillaries of the finger three-quarters of a pound and so on, till we reach the largest veins, where we find a *negative pressure* of nearly one ounce to the square inch. This means that, if such a vein were punctured,



the air would tend to rush into the vessel with this degree of pressure. We can, of course, see the danger of operating on these vessels without proper precautions.

**The speed of the blood current** varies in the different parts of the vascular system, being most rapid in the aorta, slower in the carotids, and slowest in the capillaries, while in the large veins it rises to about the speed of the blood in the carotids. The use of an instrument (stromuhr) which allows the rapid reversal of the current, in a tube length of known volume, enables us to determine the speed with fair accuracy. The *time required*, in man, to complete the *circuit* of the average course of the blood vessels in about thirty seconds.

**The capacity of the heart's cavities** is found to be from four to six ounces for the ventricles, and about a third less for the auricles. It might at first seem strange that a six ounce ventricle could be filled from a four ounce auricle, but this is explained by the fact that the ventricle is partly filled before the auricle contracts.

**The innervation of the heart in detail.** First, it must be known that the cardiac muscle fibre has the power of rhythmical contraction independent of nervous influences, and the same is perhaps true of the general muscular fibres of the blood vessels. (Traube-Hering curves.) Various experiments show, however, that it is to the various masses of ganglionic nerve cells embedded in its substance, (see page 72), that we are indebted for its regular movements. The collection of nerve cells, to which the term Remak's ganglion is applied, is found chiefly in the upper part of the right auricle ; and the fact that heart movements begin in this auricle and here cease last leads us to believe that



it is the true cardiac *excito-motor centre*. The experiments of Stannius on the frog's heart indicate that this is the dominating centre for the heart at large, and that Bidder's ganglion in the auriculo-ventricular groove is in a *less degree* the *excito-motor centre* for the lower heart; while Ludwig's or Bezold's ganglion in the auricular septum is the intrinsic cardio-inhibitor, or *depresso-motor centre*. Outside the heart, as we have seen, impulses from the nucleus of the vagus depress or inhibit cardiac action, while impulses from the sympathetic excite it.

**The influence of the respiration on the heart's action** is quite pronounced, especially in aiding the diastolic dilation of the heart's cavities. The effort of the distended elastic lung to return to its condition of elastic equilibrium, as we shall see later, through atmospheric pressure aids the filling of the auricles at least to the extent of its elasticity. It also aids in increasing the power of the lesser or pulmonary circulation.

**The usual pathological conditions** influencing the heart are (1) functional depression (syncope on "fainting") or excitement due to mechanical or nervous irritation; and (2) organic changes, which may be in the myocardium (degenerations), or in the valves. The openings of the valve may be narrowed (stenosis) or the valve may be warped and drawn until it does not close the opening (insufficiency).

In the first case fear, on any profound nervous impress, may produce either forceful palpitation or the reverse, extreme feebleness of heart, which being insufficient to supply the cerebral centers with blood, unconsciousness and loss of power (syncope) results. Lowering the head, will, by bringing gravity to the aid of a weak heart, restore consciousness. Some-



times a gas distended stomach by pressing on the heart from below will cause palpitation (carminatives.) For the organic condition stenosis we must add increased force to the muscular effort which is to force the blood through a contracted opening (digitalis) while in the so called insufficiency we must shorten the diastole or period during which the blood can leak back into the proximal cavity.

**The portal circulation**, so-called, is but a part of the systemic circuit. As we saw, the blood from the right ventricle goes through the pulmonary artery to the capillaries of the lung to be returned by the pulmonary veins to the left auricle, giving the pulmonary circuit. The left ventricle now sends this out through the aorta to the general system to be returned to the right auricle, completing the systemic circuit. A part of this blood, however, follows a peculiar route. The blood, speaking in a general way, of the *coeliac axis*, *superior and inferior mesenteric arteries* and lesser branches, is gathered into a large vein called the *portal vein*. This does not as is usual join a larger vein and pass on to the right heart, but it passes on to the liver, there to ramify in a *second set of capillaries*, to be again gathered into veins which join others, and now enter the right auricle. Contrary to what we would suppose the branches of the portal vein have no valves.

#### LYMPH CIRCULATION.

The term, **lymph circulation**, is scarcely an accurate one, for the reason that the lymph does not complete any circuit of its own, but is in reality only an auxiliary part of the general vascular system. That part of the plasma which is not used, as well as all the tissue waste, is returned from the tissues by the lymphatics. The *lymph vessels* called "lymphatics"



and "absorbents" are, when small, much like capillaries, when larger, somewhat like the veins, in both cases having valves. The valves, in form and structure, are much like the semi-lunar valves, but are usually only "two leaved." The chief trunk of the lymph system, the *thoracic duct*, leads from the great lymph sac, the *receptaculum chyli*, to the junction of the left subclavian and jugular veins, where it opens by a valve-guarded orifice. The various *points of origin* for the lymphatics are as follows. (1) The interstitial origin, or origin from the interstitial lymph spaces, is the most common, as well as the most important. (hypodermic medication.) (2) The intestinal origin, from the lymph spaces of the intestinal villi. This differs from all other lymph systems in that it carries what we call *chyle*, a milk-white mixture of absorbed fats and lymph, the white color of which gives to the vessels the name of the "lacteals." (3) The origin from stomata, which we have seen occur on many serous surfaces. These allow the absorption of excess of serous fluids. The *vis-a-tergo* of the blood in the capillaries is the chief *cause of the movement* of the lymph in its vessels, but the following other causes aid, viz.: the contractile power of the villi of the lacteals, the compression of the lymph vessels (valves) by muscular action, thoracic suction and the arterial pulse waves on the perivascular lymph spaces of bone, etc. The general course of all lymphatics is from the periphery toward the centre, by the most direct route, and there are usually two sets of vessels, a superficial and a deep.

It will be observed that the lymph in greater part leaves the blood vessels where intra vascular pressure is still relatively high ( $\frac{3}{4}$  of a lb.) i. e. in the capillaries, that from these points the anatomical course of the



## INTERNAL SECRETION.

1. Liver - glycogen - urea.
2. Pancreas - fat - sugar.
3. Kidney - urea.
4. Testes - ovaries - epiphyses - muscular capacity.
5. Thyroid - antria - strumiparia.
6. Suprarenal capsule - epinephrine - muscular irritability.
7. Pituitary body - acromegaly - PHYSIOLOGY
8. Adrenals - brain - sympathetic nervous system.
9. Thymus - spleen

lymphatics is determined by but one thing, viz. the effort to reach that point of the circulatory route where blood pressure is negative, (see page 88). Here it can return to the blood circuit without resistance.

## CHAPTER V.

### THE BLOOD AND LYMPH GLANDS.

The structures here taken up and called "glands" are not in reality glands, having no secretory epithelium, no basement membrane and no duct for the discharge of a secretion. At the same time their general appearance caused them to be called "glands" before these details were known, and we have since used the lack of a duct to distinguish them from the true glands.

**The ductless, or blood glands**, are the spleen, the thymus, the thyroid, the supra-renals or ad-renals, the tonsils, the pineal and pituitary glands, the aggregated glands (Peyer's) of the intestine, and the solitary glands or adenoid bodies of the same and other regions. The details of function in these bodies is very imperfectly known; but that all are concerned in the production or elaboration of the blood and lymph, is now generally believed. The lymphatic "glands" or compound lymph nodes will be considered after the ductless glands.

**The spleen** is the most important, as well as the largest, of the so-called blood glands. Lying within the abdominal cavity and connected by large special trunks with the portal system of blood vessels, its

INTERNAL SECURITY

Living (Ex. execution Bill  
just " " )

Winn (cont. " December 2, 1962

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Ch. 10. *Sugar* - *Carbohydrates* *Ch. 11. Fats, absorption & distribution*

Kidney - urea - limited production Proteins

Salvia gracilis -

Puberty -  
Physical & psychological changes at puberty  
due to internal secretions

Oophorii-orange form. Cupidation

ordinaria el brote .. " Musculos activos  
" .. " espontaneos

thyroid -

goitro -  
myxedema - (mucin) (Borsig-  
muco-

Destroys organisms (topic) Relevant topics

Subs. indispensable to organism

*Tadostygium* - increases extensibility of fibroblast

diminishes

new controller secretion

Sup + Inf. Thyroid

Suprarenal Cysts (Addisons disease)

Epinephrine muscular tonicity Johns neutralized

Traces. Blood pressure - faint. Slow full  
resp. contract.

(Sensory fibers) Stim. vasomotor endings

-Pituitary Body (Adenohypophysis)

Aut. late - well

Post. lobes - Tries to - Ries blood pressure - Constricts the blood vessels

position and general connections give evidence of the part it is to play.

We find it covered superficially with its *serous* or *peritoneal* layer which forms its ligaments, and beneath this is a fibrous *capsule* which invests it, and sends in *septa* or *trabeculae* to furnish the framework or *stroma* of the gland. At the hilum, or point where the blood vessels enter the spleen, this capsule turns into the interior of the gland, and dividing in various planes joins the *trabeculae* from the periphery and divides the spleen up into small lacunar spaces called *lobules*. The branches of the *splenic artery*, entering at the hilum, follow without anastomosis the planes of connective tissue between the lobules, giving off as they go terminal branches to each one. This *terminal artery* in the lobule ends near its centre in a pear-shaped expansion, seemingly as if the walls of the vessel had become an open-meshed sac. This sac-like body or *corpuscle* is in reality composed of adenoid tissue, and its open meshes are filled in with lymph *corpuscles*. The space in the lobule around this corpuscle, often called a *Malpighian corpuscle*, is filled in loosely with a dark-red granular mass of cells called *spleen-pulp*. Veins with open or *cribriform* walls take origin in the spleen-pulp of the lobule, and pass out through the connective tissue *septa* to the hilum to form the *splenic vein*. In the capsule internal *septa*, and *trabeculae*, elastic and (visceral) muscle fibres are found, the latter by their rythmical contraction, probably giving the pulsating powers of the spleen. We see from the above that the route of the blood in the spleen is through the *splenic artery* to the *terminal artery* of the lobule, here it percolates through the lymphoid cells of the corpuscle, passes out into the open meshed tissues of the spleen-pulp, through this into the open-

# INTERNAL SECRETION.

Nervous (Sensory

Sp. cord -  
gray + white Brain

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Repressor sub - direct action on blood vessels. not due to vaso-motor.

Thymus { Blood Uptaking organ  
Lowers Blood Pressure  
Accelerate heart.

Spleen - { Blood formed  
Blood Destroyed  
Aids tissue formation of  
Pancreas

ings of the outgoing veins, and thence away through the splenic vein. The degree of dilatation for the lobules is regulated by the tension of the elastic and muscular fibres in their walls. *The function of the spleen* is doubtless manifold, and yet it is not seemingly essential to any special function, for it may be removed entirely without ill result; a slight compensatory enlargement of the other blood glands alone showing that they have assumed its function. The connection of the spleen with the *digestive functions* is shown by its enlargement during the later stages of digestion, being used probably as a temporary reservoir for digestion products. Its part in *blood-claboration* is seemingly the destruction of imperfect red blood cells; for the blood coming from the spleen is peculiarly poor in red blood cells, as compared with white, (only 100 to 1), while in the blood entering the spleen the proportion of reds is greater than usual (1200 to 1). This may in part be due to the formation of leucocytes, but the presence of free pigment, (which the liver seems to use,) proves that red cells are destroyed. The muscular fibres of the spleen being under nerve (probably vaso-motor) control, we see how it may be used also as a *reservoir to relieve excessive blood-pressure, congestion, etc.*

**The thymus**, another of the ductless or blood glands located in the anterior mediastinum and neck, may be called a temporary organ. It reaches its full size and functional developement at a little over two years of age in the human subject, and later atrophies to a mere anatomical "relation." Composed usually of two, sometimes three *lobes*, it is invested in a capsule of fibrous tissue. The lobes are made up of an immense number of small *lobules*, each having a *cortical* and a *medullary* part. The cortical portion is of loose ade-



noid tissue filled in with lymph corpuscles, while in the medulla the same tissue, still more open, contains granular cells and a peculiar flask-shaped corpuscle. The function of this gland is not known, other than that it appears from structure, etc., to be a blood-elaborating organ. As found in the calf, and other young domestic animals, the thymus furnishes the "sweet-bread" of our tables.

**The thyroid**, unlike the thymus, persists in functional activity until late in life. It is somewhat larger in females than males, this being especially true of those who have borne children. In many of the lower animals it enlarges during the rutting period, most notably among the deer. Located on the trachea, it consists of two *lobes* and an *isthmus* which unites the lobes. The internal structure is shown to consist of a series of closed vesicles or sacs containing a glairy yellow fluid. The *vesicles*, of varying size, are separated from each other by connective tissue septa continuous with the capsule of the gland. Each vesicle is lined by a single layer of peculiar epithelial cells supported by a delicate adenoid reticulum. The arteries of the thyroid anastomose freely around the vesicles, and lymphatics are said to originate in their cavities. The yellow color of the vesicular fluid seems due to haemoglobin. The enlargement or hypertrophy of this gland gives rise to the disease called "goitre," so common in Switzerland and other high altitudes, where it usually is associated with cretinism. The entire degeneration or removal of this gland will in man, and in most animals, give rise to a series of neurotic and trophic changes, which may result in cretinism or death, as the case may be. The symptoms are usually tetanoid, mucoidal and then cerebral in order. *Myxoedema* is a general mucoid degeneration



which in man follows pathological changes in the thyroid. The subcutaneous transplantation of the thyroid of a sheep, or other lower animal, into the human body has produced pronounced improvement in this disease, but not so pronounced as seems to follow the continued administration of a glycerin extract of the gland itself. (*Exophthalmic goitre*, a disease characterized by intense rapidity of the heart's action and a temporary congestion of the vessels of the thyroid and orbit, is not yet proven to be due to disease of this gland.) The *function* of the thyroid seems to be evidenced in the following acts: 1. Blood elaboration, probably acting as a place of breaking up for degenerate corpuscles; 2. regulating the formation of mucin in the body; 3. and of influencing in some way the sexual functions. *Regulation Toxins*

**The ad-renals**, or supra-renal capsules, lying one upon either kidney, are found to have the following structure form without in:—a thin, fibrous capsule, a cortical layer, and next a small medullary portion. The *cortical* layer is composed of a granular sub-capsular zone and cells, arranged in radial cylinders, containing more or less fatty matter and yellow granules. The *medullary* part contains, in an adenoid framework, muscular elements, blood vessels, protoplasmic granules, and nervous elements. The latter are so abundant that many think that at least this part of the gland has ganglionic functions. The other parts have probably the general function of the blood glands. *Addison's disease*, evidenced by a peculiar bronzing of the skin, is usually found associated with disease of these structures.

**The tonsils**, located between the pillars of the fauces, are composed of a mixture of lymphoid and epithelial tissue. A number of depressions or crypts sink in



from their mucous surface, and into the bottoms of these quite a number of mucous glands open by their ducts. Around these crypts adenoid tissue, filled with leucocytes, is found and large numbers of closed or solitary follicles. A thin capsule of fibrous tissue covers all but the free side. Inspissated masses of mucus mixed with dead leucocytes, etc., are often found filling these crypts and protruding from their orifices. During the early years of life the tonsils hypertrophy quite readily, but usually shrink before adolescence. The pharyngeal tonsil (Lushka's), located on the pharyngeal vault, is of the same structure and it also hypertrophies. Only the lymphoid parts of these structures have the function of blood glands.

**The pituitary and pineal glands.** The first of these, the *pituitary body* or *hypophysis cerebri*, consists of two distinct parts or lobes, the anterior or larger embracing the posterior or smaller. The *posterior* lobe is part of the brain, to which it is united by the infundibulum. The *anterior* lobe is somewhat like an ad-renal in structure, being composed of adenoid tissue, lymph corpuscles, etc. Its function is unknown.

The *pineal gland* also consists of two lobes. The outer or *cortical* part is seemingly analogous in structure to the anterior lobe of the pituitary body. The *inner* part belongs to the brain, as above, and, contains a cavity (ventricle) lined in early life with ciliated epithelium. It was at one time supposed to be the seat of the soul—notwithstanding its size! This cerebral off-shoot, obsolete in man, has in some of the lizards, (Hatteria, etc.), developed into a median eye, fashioned on the invertebrate plan. (The coccygeal and carotid glands are not well enough understood to describe.)



**The agminated and solitary glands** are essentially the same in structure. The solitary glands, or *lymph follicles*, are found in the mucosa, and sub-mucosa of the alimentary tract, trachea, bronchi, bladder, ureter, etc. However much they differ in size, etc., they consist of small masses of adenoid tissue loaded with lymph corpuscles or leucocytes. Blood vessels enter them, but return in loops without distribution, lymphatics ramify around them but never communicate. In the centre of each is usually seen a "germ centre" with leucocytes undergoing karyo-kinetic changes. If the phagocytic theory of Metznikoff is true, these follicles may be considered as barracks for the soldiers of defence, and they are placed where needed. The *agminated glands* of the intestinal tract, Peyer's glands, are but groupings of a dozen or more of the above lymph follicles together in a peculiar manner. These "patches" are found chiefly in the lower part of the ileum, arranged under the mucosa in a linear manner, opposite the insertion of the mesentery of the gut. They *ulcerate* readily in cases of *typhoid fever* and gradually disappear with age. Their location in the gut wall, at the point most remote from the supplying mesenteric vessels, alone explains the relative rarity of severe hemorrhage in euteric or typhoid fever.

**The lymphatic glands**, or compound lymph nodes, differ from all the foregoing in that they are located on the line of the *lymph vessels* and form a part of them. They are found in great numbers on the lines of the lacteals in the mesentery, along the lymph lines of the abdomen and thorax, especially at the root of the lung. More superficially, they are found at the back of the neck, its sides and base, and under the jaw, in the axilla and arm as far down as the elbow, in the groin and sometimes in the popliteal space. (Some few lymph



vessels, however, undoubtedly join the thoracic duct without passing through lymphatic glands.) They vary in size from a bird-shot to an almond, and may be enormously enlarged.

*The structure of the lymph gland* shows first a capsule of connective tissue mixed with visceral muscle, and this capsule is turned in at the hilum to form the internal framework of the gland, and is united with trabeculae sent in from the periphery. These fibrous planes divide the gland into small spaces or *alveoli* which are large and distinct in the outer or *cortical part*, and become blended in the indefinite subdivisions of the *medulla*. These alveoli show an internal structure which somewhat resembles the spleen, *viz.*—a central mass of adenoid tissue closely packed with lymph corpuscles, around this, next to the connective tissue of the capsule and trabeculae, is a very open reticulum of adenoid tissue containing few lymph corpuscles and forming a *lymph channel* around the central mass. The afferent vessels of the gland (lymphatics) enter on the convex side, their various branches piercing the capsule and their intima becoming continuous with the endothelium of the lymph channel in the alveolus which they enter. The internal mass of adenoid tissue in each alveolus does not touch its walls, being separated by the lymph path, but at its inner extremity (next the medulla) it breaks up into several prolongations which, joining similar extensions from other alveoli, and also fibrous off-shoots from the trabeculae of the capsule, form the composite medullary structure. This medullary tissue of the gland is not so open as that of the lymph channel, nor so filled in with lymph corpuscles as the central adenoid mass of the alveolus. The lymph, having entered from the afferent vessels and traversed the lymph channel, percolates through this



open medullary substance to enter the afferent vessels and go out at the hilum. Blood vessels enter the gland at various points, run in its fibrous septa and ramify in the closely packed adenoid masses of the alveolus and medulla, the veins of these vessels emerging at the hilum. The muscular fibres of the gland seem to have an influence on the flow of the lymph, bearing some analogy perhaps to the lymph hearts of the frog and other animals. Bearing on the function of these glands: we see how septic products, etc., when absorbed, are delayed in these glands, exposed to the phagocytic and other influences of the leucocytes here abounding, and perhaps further influenced by the oxidizing power of the blood, brought into close relation with the lymph in the medulla and adenoid masses of the alveoli.



## CHAPTER VI.

## RESPIRATION.

**Respiration**, meaning literally "to breath again," is here used to describe the gaseous interchanges that take place in the blood. These interchanges take place at two points in the blood's circuit; one in the capillaries *in the lung*, called pulmonary respiration, and the other in the capillaries *in the tissues at large*, called interstitial respiration; In *pulmonary respiration* the blood in the capillaries of the lung is, by the mechanical act of respiration, exposed to the influence of the O of the air; and it takes up O, and gives off CO<sub>2</sub>, which it contains in large excess. In *interstitial respiration* the blood flowing through the general capillary system of the body is brought into intimate relation with the tissues of every part, and it gives off to the tissues for their sustenance O, which we saw it take from the air, and now takes in exchange CO<sub>2</sub>, which, as we saw, it eliminates in the lungs. The latter form of respiration requires no apparatus aside from the general circulatory system, but for pulmonary respiration an elaborate, special apparatus is required, which we will now consider.

**The pulmonary respiratory apparatus** consists of the following parts: (1) The accessory respiratory tract, including the nostrils, regio respiratoria of the nasal fossa, posterior nares, pharynx, and upper larynx; (2) the true respiratory tract, including the lower larynx, trachea, extra- and intra-pulmonary bronchi and bronchioles; (3) the lungs, made up of alveoli or air cells, blood vessels, interlobular septa, investing



pleura, etc.; and (4) the thorax, consisting of a conical bony framework closed in by soft tissues, and capable of change of volume by the action of muscles.

(1) *The accessory parts of the respiratory tract.* Considered in detail, the nostrils are found to be capable of dilatation or of compression by the action of the muscles, dilator naris, ant' and posterior, compressor narium, etc. These movements are seldom seen on the human subject, except in forced breathing, as in the asphyxiation stage of croup, etc.; but in the lower animals, as the horse, etc., their movement is pronounced. Note the stiff hairs or vibrissae at the margins of the nostrils, to catch floating particles, etc. The "regio respiratoria" of the *nasal fossa* is all that part of the fossa lying below the level of the middle turbinated bone. The function of this part of the tract is to warm and make moist the air taken in, which is done by the passage of the air over the large vascular surfaces of the turbinated bones. Observe the fact that the excess of tears are discharged into the inferior meatus of this fossa, and aid in keeping moist the passing air. The *posterior nares* have no special function as regards respiration, their closure by the soft palate being a part of the acts of deglutition and phonation rather than of respiration. The mouth cavity is in no sense a part of the respiratory tract, persons only breathing through the mouth when the regio respiratoria, (polypi) or pharyngeal vault (adenoids) is obstructed. The *pharynx* is a cavity of double function, being a part both of the digestive and respiratory tracts. For the exercise of the function of deglutition it can be cut off from all respiratory connection above by the soft palate, and below by the epiglottis. The upper larynx is in reality a part of the pharynx, and may be here so considered.



(2) *The true respiratory tract* may be said to begin at the vocal cords. The opening of the glottis, or *rima glottidis*, may be divided into two parts ; that between the cords or anterior part, called the *glottis vocalis*, and that between the arytenoid cartilages or posterior part, called the *glottis respiratoria*. Notwithstanding the fact that both cords and cartilages may be widely separated, this is the most dangerous part of the respiratory tract, in so far as ease of obstruction is concerned. Foreign bodies of all kinds, from safety pins to lumbricoid worms, are found obstructing this opening ; inflammations simple (oedema *glottidis*) and croupous rapidly close it, while ulcerations leave cicatricial bands that narrow, and ultimately even close it. Lower down in the trachea and larger bronchi we find the **C** shaped rings of cartilage and their complemental trachialis muscle, giving an air tube firm yet flexible, open yet compressible. A section of the duct here shows (a) ciliated epithelium with its germinating layer at its base ; (b) a basement membrane which overlies the submucous areolar layer, in which we find small blood vessels, lymph vessels, nodes, etc. ; (c) a longitudinal layer of elastic fibres overlying the true submucous areolar layer which contains large blood vessels, lymph vessels, nerves, mucous glands, etc. ; (d) the cartilages and muscle, fibrous envelope, etc. As we descend toward the lung, layer after layer is lost, as follows : the cartilaginous rings become irregular plates and disappear, the muscular fibres increase and become circular, and the areolar layers disappear step by step till we find in the smallest bronchi or bronchiole the following :—internally, ciliated epithelium now almost cubical and bare of cilia, next the longitudinal elastic layer unchanged, then circular muscular fibres (asthma), a thin



submucous layer containing vessels, nerves, etc., and a thin fibrous layer continuous with the interlobular septa. It may be stated here that the cilia move upward towards the larynx and carry mucous and foreign particles of all kinds to the rima glottidis, whence they are removed by coughing. This action of the cilia, as well as the sensibility of the nerves of the larynx, etc., is depressed by the action of opium and anaesthetics.

(3) *The lung structure in detail.* When the bronchial tubes become very minute (1-25 of an inch), they become beset all around with air cells called "alveoli," and from this point they are called alveolar passages. As they continue outward they are surrounded by larger cavities, the inner walls of which are also beset with alveoli, these larger cavities being called "infundibula." Each terminal bronchiole with its alveolar passages, infundibula and their alveoli forms a "lobule," and is separated from its fellows by interlobular-septa derived from the fibrous trabeculae of the pleura. A pulmonary air cell or alveolus is a small cavity (1-100 of an inch in diameter), found on the periphery of a terminal bronchiole, or on the inner surface of the infundibula, lined by flat squamous cells, with swollen granular cells at intervals. These flat cells rest on an open membrane composed of fibrous and elastic tissue, with scattered non-striated muscular fibres. Between the squamous cells and the basement membrane wind the capillaries of the pulmonary artery. The surface offered by the aggregate area of capillary wall exposed to the air in the alveoli is enormous; being estimated at 1,500 square feet. The capillaries contain over 3 pints of blood which is renewed every 8 or 9 seconds. Covering over the entire lung and investing all its lobes is a thin fibrous membrane called the *pleura*. From the general sur-



face it extends over the "root" of the lung, on to the bronchi and large vessels that enter here, and from these trunks it is reflected back over the lung again as an investing sac. The inner layer of the visceral or pulmonary pleura is of fibrous tissue, and it sends in trabeculae to unite with the fibrous extenstions of the smaller bronchioles. The outer layer of the visceral pleura is endothelial, but of course the reflection at the root of the lung brings a change in the relationship of these layers on the parietal pleura, and makes the outer layer the inner.

*The lung substance in the foetus*, never having had its air cells or alveoli distended by respiration, is compact and heavy and will sink in water. The lungs after distention will not only float, but as a rule, will sustain the attached heart. After decomposition sets in, the lungs *may* from the retained gases of decomposition float *temporarily*.

*The blood supply of the lung* is from two distinct sources, *viz* :—the pulmonary artery and the bronchial arteries. The blood from the *pulmonary artery*, following the bronchi, courses ultimately in the capillaries in the walls of the alveoli to be *aerated*, and takes no part in the nutrition of the lung. The blood from the *bronchial arteries* following also the bronchi, and their connective tissue prolongations, *supplies nutrition* for the general lung tissues. These arteries do not anastomose in any part of their course, although following the same routes. Their respective veins do anastomose, however, to a slight extent. This is sometimes a serious matter; for it must be remembered that the pulmonary vein carries arterial blood, and if there be any obstruction to the flow in the bronchial vein the impure blood of this vessel is thrown into the arterial blood of the general system. It is said that the collect-

Calorimetry insulation time = 13 minutes

Open Water Start in Water = 700 minutes

Calorimetry insulation time = 100 Sq. metres (Calorimetry insulation time = 100 Sq. m. occupied by insulation)

8 μ insul.

ive area of the pulmonary veins is smaller than that of the pulmonary arteries. If this be true, it is accounted for by the great loss of fluid from the blood by evaporation in the pulmonary capillaries.

*The lymphatics of the lung* are a deep and superficial set; the deep having an interstitial origin and following peri-vascular and peri-bronchial channels, while the superficial set arise from pleural stomata and run in sub-pleural channels. The lymphatic glands on these vessels, called bronchial glands, are a dozen or more in number and located at the root of the lung. In the aged they are almost black in color.

*The nerves of the lung.* Small *ganglia* are located along the lines of the nerve trunks which follow the bronchi and in the mucosa. The nerve *fibres* are from the sympathetic and *pneumogastric*, the latter furnishing motor (efferent) fibres for the tracheal and bronchial muscle and sensory (afferent) fibres from the lung to respiratory and other centres.

(4) *The structure of the thorax* shows it to be designed for mobility with strength, the ligamentous union of spinal column, ribs, sternum and cartilages, pointing to this intent. In detail it consists of a strong but light conical bony framework having all its openings filled in. The diaphragm closes the lower opening, the parietal fascia, muscles, pleura, etc., the spaces between the ribs, and the numerous structures passing through the upper opening, with the thoracic fascia, close it also.

**Expansive power of the thorax.** Laying aside the action of the diaphragm in directly increasing the capacity of the chest, the thorax can be increased in diameter both antero-posteriorly and transversely. Its *antero-posterior diameter* can be increased by raising the sternum and attached ribs, as by the action of the



scaleni muscles, etc. This increase in diameter is due to the fact that the points of spinal attachment of the ribs lie on a higher level than their points of sternal attachment, so that the elevation of their anterior extremities increases the diameter to the full length of the rib, from point to point. The increase in *transverse* diameter is made in a much similar manner. The "droop" of a rib is such that the mid-point of its shaft lies below a line drawn through its spinal and sternal points of attachment; and this brings the mid-point near to the median line of the body, just as a wooden roller on the handle of a bucket is nearer to the vertical axis of the bucket when lying against its side, than it is when the handle is level. When all the ribs are raised till the "droop" becomes horizontal, the lateral transverse they all make from the median line increases the transverse diameter of the chest.

*The muscles of the thorax* whose action influences thoracic capacity may be divided into three groups. (1) Those *elevating* the sternum and ribs and *increasing thoracic capacity* (inspiration), as the levatores costarum, serratus posticus superior and external intercostals, for ordinary breathing, with the scaleni, sterno-mastoid, serratus magnus, pectorales, trapezius, etc., etc., when extraordinary breathing efforts are made. (2) Those *depressing* the ribs, sternum, &c., and *decreasing thoracic capacity* (expiration) as the abdominal muscles, internal intercostals, triangularis sterni, serratus posticus inferior, &c., which muscles act only, however, when extraordinary breathing efforts are being made. Ordinarily the depression of the ribs, &c., after elevation, is produced *without muscular action*, the *weight* of the chest, arms, &c., the elasticity of the stretched abdominal muscles, costal cartilages, &c., and the elasticity of the lungs, being sufficient to cause the fall. (3) The dia-



phragm does not materially change the external *shape* of the thorax by its action, but being arched upward from its points of attachment, its contraction depresses it, and hence *increases* to that extent the length and *capacity of the thorax*. The central tendon being blended with the fibrous pericardium moves but little, and the chief change takes place in the lateral segments. The lower ribs would be drawn inward and upward by the contraction of this muscle, were it not for the action of the quadratus lumborum, etc., in fixing them fast. In other words an *inspiration* is made by dilating the thorax, the inspiratory muscles for ordinary tidal breathing being the levatores costarum, serratus posterioris superioris, external intercostals and diaphragm. An ordinary *expiration* is made simply by the action of gravity and tissue elasticity. The muscles of forced expiration are the abdominal muscles and others named above.

*The mechanism of respiration.* In the process of ordinary (tidal) respiration, the movements of the chest which cause the air to rush into, and then out, of its cavity must overcome some force, and we will take these movements and forces in detail.

*In ordinary inspiration* the muscles before mentioned raise the ribs and sternum, and the antero-posterior and transverse diameters of the thorax are increased ; at the same time the diaphragm contracts and increases the capacity of the chest longitudinally also. The capacity of the chest being increased, atmospheric pressure within the thorax falls ; i. e., the air in the chest which entered at a pressure of one atmosphere (15 lbs. to the sq. in.) is now at less pressure. But through the respiratory tract the atmospheric air communicates with the interior of the chest, and air rushes in through the nostrils and tract, and into the lungs until pressure in

16. 15 = 9. 16  $\frac{16}{20} \times 100 = 80\%$   
20. 25 = 7. 62  $\frac{7.62}{20} \times 100 = 38\%$   
Ratio Respiratory =  $1 - \frac{1}{2} = \frac{1}{2}$

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the lung and external air is the same. This completes the inspiratory act. The forces which are overcome in this movement are, as we have seen, the weight of the chest, the elastic tension of the abdominal muscles, costal cartilages and lung structure. If now we relax the muscular action which distended the thorax, the forces above named act, the ribs and sternum fall and the diaphragm rises. This decreases the thoracic capacity, and its contained air is subjected to a pressure greater than that of the atmosphere, and rushes out by the same channels through which it entered. This is an ordinary expiration, and these two acts repeated rhythmically give tidal respiration. If respiration is rapid, i. e., so rapid that the thorax dilates more rapidly than air can enter through the respiratory tract to equalize pressure, the force of atmospheric resistance must be added to the above. This in tidal breathing is nominal, but in laryngeal or similar obstruction it is most marked and is shown by the sinking in of the intercostal spaces during inspiration.

**Beginning of Respiration.** Unlike the heart, which beats for months in utero, the lungs first get their fill at birth. A child in utero lies with arched spine and compressed abdomen and chest. The legs being folded on the abdomen press upon the abdominal viscera forcing the abdominal contents up into the concavity of the diaphragm and causing it almost to fill the thorax. When after expulsion from the womb the child is allowed as it were, to unfold, the abdominal contents first assume their normal position and the diaphragm descending with them leaves the thorax almost empty. This would tend to create a vacuum in the chest but for the fact that the lungs which have hitherto lain in the upper part of the chest unexpanded, are now filled by the force of the atmospheric air



which rushes in through the trachea, etc., and by the force of its pressure distends the lung as the diaphragm recedes. At this time by a combined series of reflexes which we will later appreciate an inspiration is initiated, and breathing begins. This reflex is in all probability due primarily to the stimulus of cold, the relative difference in temperature between the uterine cavity and the average bed room being immense. We all know the deep inspiratory effort induced by the shower bath or the pranks of the rural swimming pool. At all events there is no method of producing lively respiratory movements in the new born child compared with that of the sudden sprinkling with *cold* water (atelectasis).

**The elastic traction of the lung** can be best understood by an illustration. Let us take for example a large open glass bell jar, which will represent the thorax, pass through the cork in the neck of this a forked glass tube which will represent the trachea. Over the mouth of each arm of this tube tie a collapsed rubber toy balloon and then tie a sheet of thin rubber over the mouth of the glass jar, with a string fastened to its centre on the outside. Now, from a stop-cock exhaust the air in the bell-jar, and we will see the diaphragm rise and will also see the balloons gradually become distended until they fill the entire space in the bell-jar. If now we pull on the string and depress the diaphragm, we see the balloons follow the diaphragm in its movements, while air rushes in and out of the open end of the forked tube as the diaphragm rises and falls. The balloons represent the lungs in their normal position, and whatsoever of space exists between them and the walls of the glass jar, represents the so-called pleural "cavity". Now open the stop-cock and we will see the air rush in



here, and the balloons will gradually collapse to their original size, while air will, in equal ratio, rush out at the open end of the forked tube. This the balloons will do when the stop-cock is open, whether the diaphragm be high or low, but more powerfully when low. The deductions from this are simple—the lungs are distended and held against the parietal wall by atmospheric pressure, and in this state their elastic elements are put upon the stretch, less at expiration than at inspiration, but great at all times. If the chest be opened and atmospheric pressure be the same on both sides of the visceral pleura, the lung will collapse owing to its desire to return to a state of elastic equilibrium. The constant force which it exerts to leave the inside of the thorax and its contained organs, against atmospheric pressure, is its elastic traction.

The influence of the *traction of the lungs* in the *dilation of the heart* may be studied with the same apparatus. Let us take a soft compressible rubber bulb provided with a rubber tube which passes out through the diaphragm and ends in a fluid in a glass. Now, as before, exhaust the air in the glass bell-jar through the cock and we will see the balloons expand and fit around the rubber bulb which also dilates from the rising of the fluid into it through the tube. Now pull down the diaphragm and note the result. As the diaphragm descends more fluid rises in the bulb; for when the internal capacity of the bell-jar is increased, atmospheric pressure in it falls (temporarily) and the normal pressure on the fluid in the glass forces the fluid up through the tube into the bulb. Conversely, when the diaphragm is pushed up and the pressure consequently rises, the fluid will fall to a slight extent, but only to a slight extent, for the elastic traction of the balloons keeps the bulb and its tube dilated and full at all



times. If a puncture could be made in the bulb, the fluid would pass through it into the bell-jar till the glass was drained, while the balloons would recede as the fluid came in. We can see from the analogy how the traction of the lung on the heart keeps up a tendency to dilation, and how the blood is forced in from the large veins which come from without the thorax, and how this aids the right auricle and in turn the right ventricle. We can see, in addition to this, how the same influences on the pulmonary vessels would produce a fullness of these vessels during inspiration, and pressure on them during expiration, which pressure, as the pulmonary valves will allow the blood to flow but one way, drives the blood into the pulmonary veins and left auricle.

**The nerve mechanism of respiration.** Any one who will experiment on himself will see that respiration is a voluntary function, whenever he so wills to use it. At the same time he cannot fail to see that at the moment he takes his mind off of its direction it lapses into an automatic movement which is equal to his needs, and gives him no concern. Upon further trial he will, however, learn that while his voluntary control extends to the point of stopping respiration, he cannot stop it long ; a time soon comes when in spite of the will it must start again. It is in fact an *involuntary function*, although the muscles that produce it are *voluntary muscles*. Its control, like that of all great functions, is presided over by a special nerve centre.

**The respiratory centre** lies on the floor of the fourth ventricle, in close proximity to and perhaps involving the nucleus of the vagus. In ordinary or tidal breathing it is stimulated to action by afferent impulses received from the lung through the vagus. These impulses come from nerve terminals in the



substance of the lung which respond to *pressure stimuli*. When an expiration is made, and intra-pulmonary pressure rises, a terminal which will respond to this degree of pressure is stimulated, and sends an impulse to the centre. This impulse calls for a reflex movement, which is answered as follows:—Impulses go down the cord to the roots that make up the phrenic nerve, calling for the action of the diaphragm, others to those intercostal nerves that stimulate to action the external intercostal muscles, and still others to the posterior dorsal nerves that call into play the levatores costarum, &c. This produces, as we know, an inspiration; and as intra-pulmonary pressure falls, a terminal in the lung which will respond to this degree of pressure is excited to action, and sends an impulse to the center which is answered by a cessation of the above muscular acts, and the influence of gravity on the elevated chest, &c., aided by the elasticity of the lungs, cartilages and abdominal muscles causes an expiration. This, as we saw, produces an inspiration, and thus automatic *reflex respiration* is maintained. When more than ordinary respiratory effort is needed, the centre by other impulses down the cord calls the abdominal and other expiratory muscles into action. It also, if needed, calls the accessory inspiratory muscles to the aid of those ordinarily used. As we know, we can inhibit the response to these impulses by the will, but whenever we relieve the centre of this inhibition it will act. If the action of the will in checking respiration continues too long, another influence on the centre comes into play—the centre can be stimulated *directly*. As we will learn, when respiration is checked  $\text{CO}_2$  accumulates in the blood. This is the great excitant of the respiratory centre (as well as of the

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vaso-motor) and when a sufficient amount of it has accumulated in the blood the centre is so strongly influenced that, in spite of the inhibition of the will, it sends out its call to the muscles and respiration begins. This is called central or "*chemical*" respiration.

Experiments in proof of the foregoing may be made as follows : (1) Cut one vagus and little or no effect on respiration is produced ; (2) cut both vagi and for a time respiration ceases, and then begins, by a series of deep gasping efforts that fill the lungs to their utmost, but the rate of respiration is only half the normal ; (3) stimulate the central end of the cut vagus and respiration is increased. The following proof of the susceptibility of the centre to  $\text{CO}_2$  exists. Tie two dogs on a table side by side back down, and call them A and B. Anæsthetize them, and cut the common carotid of each, next the other, and insert into these cut vessels tubes so that the blood from the central end of each vessel will flow into the distal end of its fellow. Now ligate the other carotid of each dog. Now the brain of each dog is supplied by the blood of its fellow ; and if we ligate the trachea of B we will find that he continues to rest easily, while his fellow A, who gets his  $\text{CO}_2$ , struggles violently and makes forced respiratory efforts.

*Subordinate centres for respiratory efforts* seem to exist in the ganglionic cells of the spinal cord at the level of the distribution of the various nerves that supply the respiratory muscles. Cut the cord in a frog just below the medulla and respiration ceases ; but if the cord be cut at the same level in a frog whose centres have been rendered very irritable by the injection of strychnine, feeble respiratory efforts will be made for some time.



**Modified respiratory movements.** *A cough* is an expiratory blast or series of blasts discharged reflexly from the centre by impulses received through the vagus. While usually from the terminals of the vagus in the larynx, trachea, bronchi or lungs, other branches may produce it, as "ear-cough" from the auricular branch, "stomach-cough" from the gastric, and "palate-cough" from the pharyngeal branches. *Hawking* is but a modified voluntary cough, to remove mucus, &c., from the tract. *Sneezing* is produced by an expiratory blast through the nose, preceded by a slow involuntary inspiratory spasm and opening of the post-nasal passages. The impulse usually comes from the nasal or other neighboring branches of the fifth cranial. *Snoring* is the result of a relaxed pendulous soft palate, which vibrates with each expiratory blast. *Hiccough* is the result of an inspiratory spasm of the diaphragm, with closure of the glottis. It is the result of gastric irritation of the vagus terminals, or of irritation of the centre by toxic matters, urea, bile, &c., in the blood.

Among the *reflex influences* on the *respiratory centre*, other than those just cited, may be mentioned : (1) The spasmotic inspiratory effort produced by the sudden application of surface cold, which is of such value in starting respiration in the new-born; (2) The reflex inhibition of respiration, through the glossopharyngeal, that occurs during deglutition; (3) The emotional inhibitory reflex that occurs in a crying child, "holding its breath;" and (4) The inspiratory inhibition and expiratory spasm that occurs from stimulation of the superior laryngeal by a foreign body at the rima glottidis.

**Capacity of the human thorax.** The sum total of



the air capable of being taken into the thoracic cavity may be divided as follows:

	Cubic Inches.
Tidal Air—That going in and out during ordinary respiration.....	20
Complemental Air—That which can be taken in after an ordinary inspiration .....	100
Reserve Air—That which can be expelled after an ordinary expiration.....	100
Residual Air—That remaining in the lung after the most complete expiration.....	100
	<hr/> 320

This is, of course, simply an average capacity, some are below it and some largely above it. The estimate of 20 c. i. for tidal air is rather low.

**The vital capacity** is the measure of the greatest amount of air that can be taken into the lungs and expelled at a forced expiration. It is the sum of the tidal, complemental and reserve air or about 220 cubic inches. (Spirometer.)

As residual air cannot be expelled during life, but only after opening the plural cavities, it does not figure in the vital capacity.

The circumstances which chiefly affect the *vital capacity* are: (1) The *height*, each inch above the normal (5 ft. 8 in.) giving an increase of about 6 cu. in.; (2) The *body weight*, when above normal, is accompanied by a deposit of fat in the thorax which decreases vital capacity; (3) The *age*, in youth from deficient size and muscular power, after 35 from increasing stiffness of the thorax, &c.; (4) *Sex*, which both by influencing size and deficiency of muscular development, reduces it. Among pathological conditions disease of the thoracic and abdominal organs disturb it most.

**Diffusion of gases.** The law of diffusion is a necessary factor in the performance of the respiratory

Expiratory = 500 c.c.

Complementary = 1500 c.c.

Respiratory = 1500 c.c.

Respiratory capacity = 3500 c.c.

Residual = 800 c.c.

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function. The air that is habitually found in the lung (the sum of the residual, reserve and tidal air) is changed only to the extent of 1-8 or 1-10 at each respiratory effort. We have seen that the tidal air is but from 20-25 c. i. and as this will not fill the trachea and larger bronchi it is apparent that none could ever reach the lung were other agencies not at work. In short without diffusion as an aid, forced respiration would be constantly demanded.

**The number of respirations** is influenced by age and many other causes. At birth it is about 40 per minute and at maturity 20 ; from which time to middle life it is 18, and thence on it is slightly increased. Influencing conditions, other than age are, (1) an active or passive condition, as being in motion, asleep or awake; (2) position of the body, whether recumbent sitting or standing ; (3) disease, &c. Temperature makes but slight change so long as we can regulate body heat, but beyond this point it increases very rapidly, although not proportionately.

**Relation of respiration to pulse-beat.** *Ordinarily* the ratio existing between these functions is 4 to 1, or 5 to 1, in favor of the heart. Emotional excitement increases both pulse and respiration, but does not materially alter the ratio. Upon *exertion*, however, the increased production of  $\text{CO}_2$  gives rise to more irritability of the respiratory centre than of the cardiac, and breathing is increased in greater ratio. On the contrary, in *fever* the hot blood as well as the increased  $\text{CO}_2$  influences the centres, and as a rule, in simple fever the pulse is relatively more rapid. Some diseases, like rheumatism, give a very rapid pulse in proportion to the respiration ; others, like pneumonia, an excessive respiratory ratio ; but the general rule holds that at least in the early stages of disease a serious discrepancy



in the above ratio indicates some trouble in the nerve centres, i. e., some cerebral disorder.

**The modes of breathing** differ in the sexes, being chiefly *abdominal* or diaphragmatic in *men*, and *costal* or thoracic in *women*. The cause of this variation is not altogether understood, but it probably arises from the following combination of influences, viz., the influences of maternity, which requires thoracic breathing, the influence of corset or dress compression requiring the same, and the relative rigidity of the thorax in man, which also points to the divergence we see existing.

**Difference in inspired and expired air.** (1) *Chemical changes.* Everywhere on the earth's surface atmospheric (inspired) air gives the following analysis (volume), under which we have placed that of expired air for comparison.

	Oxygen (O)	Nitrogen (N)	Carbon Dioxide (CO <sub>2</sub> )	
Inspired Air	21	79	.04	per cent.
Expired Air	16.5	79	4.5	(?) per cent.

The analysis of expired air under the atmospheric or inspired air shows a marked loss of O and a decided gain in CO<sub>2</sub>, the exact ratio between the oxygen retained and the CO<sub>2</sub> given out being 4.78 to 4.39.

Observe that CO<sub>2</sub> is in atmospheric air at the rate of only 4 parts in 10,000. An increase to 7 parts is deleterious, 10 parts very injurious, and much above this rapidly toxic. This is not due so much to the CO<sub>2</sub> per se, as to certain organic compounds with which it is associated, and of which it is our best measure. These organic compounds probably belong to the class *leucomaines*. In addition to these, we have in expired air broken down epithelium, fatty matters, etc., with sometimes H<sub>2</sub>S and other mephitic gases absorbed from the intestine by the blood.

*Respiratory quotient = quantity of vol. of O given out as CO<sub>2</sub> / vol. of O given in. It shows proportion of O used to oxidize C.*  
 in man on mixed diet + Res. quo. 2.8-9  
 rich fat diet 2.0-2.1 lean meat intermediate. Carb hydrate 1.0-1.1



(2) *Changes in temperature.* Expired air is in temperature always very close to body heat. Whether inspired at a temperature below the freezing point, or at a temperature far above the body heat, it will be expired but little above, or below, as the case may be. If the air be warmed, as it usually is, the amount by volume is seemingly increased, although owing to more O being absorbed than CO<sub>2</sub> given off, it is really by volume 1-50 less.

(3) *Changes in moisture.* During ordinary respiration expired air is saturated with moisture. The percentage falls during rapid respiration, especially if the inspired air be warm and dry.

**The gaseous interchange in the lungs.** The exchange between the gases of the blood and those of the air in the pulmonary alveoli is not perfectly understood, but enough is known to render it certain that it is primarily dependent upon the *chemical affinity* of the haemoglobin for O. The CO<sub>2</sub> on the contrary is given up to the air of the alveoli by a process of simple *diffusion*, and at a rate dependent upon the difference in tension between the CO<sub>2</sub> in the air of the lung and in the blood of the capillaries. The belief of some (Bohr) that the glandular cells of the alveoli play a part in the dissociation of these gases is not altogether devoid of support.

**The gaseous interchange in the tissues.** *Internal respiration* is carried on under very different conditions from those we see existing in the lung. There is no varying pressure as in the respiratory act. The avidity with which O is seized upon by the protoplasm of the tissues and enters into their molecular structure leaves little or no oxygen pressure in the tissues. On the contrary the CO<sub>2</sub> formed, having no great affinity for any of the compounds of the tissues, accumulates,

O<sub>2</sub> contained in <sup>chemically</sup> Compounds -  
C. 1-2% by vol. in Serum,

O<sub>2</sub> partly dissolved  
O<sub>2</sub> partly chemically combined  
Serum - larger part than Cell -

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as Carbonate (Sodium - phosphate as

and as a result  $\text{CO}_2$  tension in the tissues is high till relieved by the passing blood. The most active sources of  $\text{CO}_2$  are the muscles and the observation that  $\text{CO}_2$  will still be given off in a muscle if a simple saline solution be substituted for the blood-stream leads us to the belief that the O in the protoplasmic molecule is not used for immediate oxidation purposes, but is added to the general reserve fund of the body, to be used as needed.

**Apnæa, Dyspnoea, Asphyxia, &c.** When a person by will power makes for some moments deep but rapid respiratory efforts, such a saturation of the haemoglobin with O occurs that the respiratory centre is depressed (satisfied) to the point that it will not for a time send out impulses to breathe, and we call this condition *apnæa*. Whenever the condition of ordinary easy tidal breathing, called *eupnoea*, is passed, and many of the accessory muscles of respiration have to be called into play, we call this state *dyspnoea*. If this condition progresses till, in spite of the intense stimulation of the respiratory centre by the accumulation of  $\text{CO}_2$ , and in spite of the discharge of the most intense respiratory impulses to all muscles that can aid in relief, sufficient O to maintain the vitality of the nerve centres and other tissues is not obtainable, the subject dies, and we call such a death *asphyxia*. Note that the conditions here are such that if after *apparent death* we relieve the cause of the asphyxia and supply the centres with O *before molecular death has taken place*, we can restore life. As, however, the respiratory centres can make no effort to supply O, and will soon lose their remaining vitality without it, artificial respiration or some other method of giving O *at once* is the only hope in cases of strangulation, drowning, &c. The *stages of death by asphyxia* are, (1) labored inspiratory move-



ments, then (2) labored expiratory efforts, ending in (3) general muscular spasm which is succeeded by the (4) relaxation of exhaustion, and (5) a final weak inspiratory spasm. A full right heart and an almost empty arterial system are evidences of this form of death, these conditions being produced by vaso-motor spasm, the result of  $\text{CO}_2$  poisoning.

**The respiration of foreign gases.** The *indifferent* gases are  $\text{CH}_4$ ,  $\text{H}_2$ , and  $\text{N}_2$ , for they will not unite with the corpuscles. The *poisonous* gases  $\text{CO}$  and  $\text{CNH}$  form permanent compounds with haemoglobin. This is itself the cause of death with the former, but the latter kills directly. Of the *narcotic* gases,  $\text{CO}_2$ , in a pure state, is not fatal up to a large per cent.;  $\text{N}_2\text{O}$ , "laughing gas," forms temporary union with haemoglobin with the production of temporary anaesthesia, and if continued it kills. Of the *reducing* gases  $\text{H}_2\text{S}$  disturbs the oxygen of the corpuscles, forming  $\text{H}_2\text{O}$  and  $\text{S}$ ; while  $\text{PH}_3$ ,  $\text{AsH}_3$ , and  $\text{SbH}_3$ , absorb  $\text{O}$  and form acids, and  $\text{C}_2\text{N}_2$  decomposes the blood. The *irrespirable* gases  $\text{NH}_3$ ,  $\text{Cl}_2$ ,  $\text{Br}_2$ ,  $\text{I}_2$  and many various acid vapors cause spasmotic closure of the glottis, by irritation of the mucous membrane of the respiratory tract.

**Cutaneous respiration.** With the water of perspiration given off by the skin will be found from one to two drachms per day of  $\text{CO}_2$ . The amount of  $\text{O}_2$  taken in by the skin is still less. The water given off by the skin is usually one-third more than that given off by the lungs, while the  $\text{CO}_2$  is only about 1-200 of that by the lungs. These ratios vary infinitely, depending upon exercise, temperature, etc.

**The contamination of air** by a person varies with the conditions of sleep, rest, exertion, sex, age, etc. As engaged in the usual duties of life an adult man pro-



duces hourly .6 of a cu. ft. of  $\text{CO}_2$ . This is gotten by multiplying the tidal capacity (20) by the number of respirations ( $20 \times 60$ ), reducing to feet and finding what proportion (4.38) of this is  $\text{CO}_2$ . The amount of vitiation allowed is .06 per cent. of expired  $\text{CO}_2$ ; or 6 parts only in 10000.

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## CHAPTER VII.

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### FOOD AND DIGESTION.

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#### FOOD.

The food of all animals including man can be divided into but *four kinds*, three of which correspond to the chemical bases of the body, studied as *proteids carbohydrates* and *fats*; to which we may add the *inorganic* foods, water and the various essential salts.

The **proteid foods** include all flesh, other than fat, milk and its derivatives, eggs, and the reproductive parts of grains, fruits and vegetables. The general percentage composition of the proteids is, as we have seen before,  $\text{C}_{50}\text{H}_{7}\text{N}_{18}\text{O}_{23}\text{S}_2$ . *Flesh* may be obtained from the ox, sheep, pig, wild animals, domestic fowls, fish, etc. It is nearly 75 per cent water, and contains as its nutritious elements myosin and other globulins, serum albumen and albumenoid principles. *Milk* is intended chiefly for the use of the young, and contains all the elements of a typical food. Its various casein derivatives, curd, clabber and cheese are much more rich in proteid constituents than milk itself. *Eggs*, as foods, represent to the embryo of the oviparous animals what milk does to the mammalia. Its food value lies in the egg albumen and vitellin it contains. The proteid elements of the *cereals* lies in the gluten, but



the *leguminous seeds* contain, in the form of legumin, twice as much nitrogenous matter.

**The carbohydrate foods** include, as we saw, the starches and sugars, with their various modifications. Starch is found as the chief constituent of the cereals, maize, potatoes, etc., while sugar (saccharose) is abundant in the cane and beet. The amount of sugar in even the sweetest fruits is relatively small, and sugar from this source plays no practical part in the diet, but the very essential vegetable acids these fruits contain make them useful foods.

**The fats and oils**, as foods, are found in butter, bacon, lard, suet, and the fixed vegetable oils, as cotton-seed oil, olive oil, etc. The animal products contain olein, palmitin and stearin, but the vegetable oils, as a rule, contain no stearin.

**The inorganic foods.** With the exception of water, the members of this class, while imperatively needed, are needed in extremely small amounts, so small that in eating the general food allowance they are incidentally obtained. Sodium chloride is perhaps an exception, so much being required that it is also taken as a condiment. Calcium and potassium salts are found in both meats and vegetable foods.

**The artificial preparation of foods**, to aid their digestibility, is limited with most foods to *cooking*. Heat applied to *meats*, either as dry heat or hot water, coagulates the surface albumen and causes the retention of the more volatile essences. The further heating coagulates all the albumen, etc., and gelatinizes the connective tissue, in both cases rendering them more digestible. If the essences are to be *extracted* for food, obviously a temperature below boiling must be applied, while salt should be added to dissolve out the globulins, etc. *Starches* are rendered much more digestible



by boiling, the starch granules swelling and bursting their cellulose envelopes. *Bread* is made more open and porous by the expansion of the gases in its doughy substance under the influence of heat. The contained gases may be air worked in mechanically, but it is usually  $\text{CO}_2$  evolved from bicarbonate of soda or generated by the action of the yeast plant (*torula cerevisiae*) on the sugar of the dough. The coagulation of the gluten sets the rise.

**Variations in diet.** The conditions of diet for health require that the total quantity of food be not only sufficient, but in the proper proportion and digestible. The amount of *water free* food needed for a man at ordinary work, is about 24 oz. per day, in about the following proportions: proteid food 1 part, fatty foods .6 of a part, and carbohydrates 3.5 parts. As we will see in the study of metabolism, the proteids subserve a function that cannot be assumed by the others, while the carbohydrates and fats, in proper proportion, are more or less interchangeable.

#### DIGESTION.

With the exception of water, the salts, and various forms of fruit sugars, the foods previously mentioned have to be modified in constitution before they can be taken into the system and made a part of its substance. The chief function of the digestive organs is to render capable of absorption the materials otherwise not available, and all the mechanical aids, as mastication, deglutition, insalivation, &c., are subservient to this chief end. As this end is practically obtained by converting colloidal bodies into crystalloidal bodies, this may be said to be the aim of chemical digestion. These processes differ in the various parts of the alimentary tract, and we accordingly divide the tract into parts as indicated by functional differences existing. Taking



the *reaction* of the digestive medium as a basis of division, we get *mouth*, *stomach*, and *intestinal digestion*.

**I. Mouth digestion**, as it is called, includes that series of digestive phenomena which take place between the lips and the cardiac end of the stomach. It therefore anatomically includes the mechanical grinding of the food, called *mastication*, and that elaborate reflex act of swallowing, called *deglutition*, as well as the special digestive act, *insalivation*, peculiar to this part of the tract.

**Mastication** is performed by crushing and grinding the food between the teeth of the upper and lower jaw. Civilized habits have, in man, rendered the prehensile incisors and tearing canines almost functionless, the premolars and molars doing the bulk of the work. The vertical motion of the lower jaw, which crushes, is made by the action of the temporal, masseter and internal pterygoid, while the grinding action is produced by the alternate (single and conjoined) action of the external pterygoid. All muscles of this group are supplied by motor branches of the 5th cranial. The depressors of the lower jaw are the mylo-hyoid\* (5), genio-hyoid (12), and anterior (5), and posterior (7), bellies of the digastric. As the food is crushed and ground it is driven from between the teeth and requires to be replaced. The internal muscle of replacement is the tongue or lingualis (12), while external replacement is done by the orbicularis-oris (7) and buccinator (7).

**Insalivation** includes the proper secretion of *saliva* and its admixture with the food. Saliva is the essential digestive secretion of the mouth, and contains the hydrolytic ferment *ptyalin*. It is produced by the following glands in decreasing amounts: *parotid*,

\*These numbers refer to the cranial nerve supply.

Male, 20 months, Canine, 165 lbs, male

Canine, 20 months, 165 lbs, male

2 1 2 3  
11 9-10 17-18  
3 15

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Regulation of oxygen consumption

metabolism

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mo.

Breast - 6  
12 months 12  
Canine 165  
24 months 24

submaxillary, sub-lingual and the scattered mucous glands.

**The parotid gland**, located around the glenoid fossa, discharges its secretion by Stenson's duct, which opens on the mucous surface of the mouth, opposite the second molar tooth of the upper jaw. It is a "serous" or true salivary gland and is the chief source of the ferment ptyalin. Its secretion contains also small quantities of carbonate of lime (calculi) in solution, and a variable amount of sulpho-cyanide of potash.

**The submaxillary gland** lies in the submaxillary fossa and its secretion is discharged by Wharton's duct, which opens on the apex of the papilla under the tongue. This gland is a mixed one, part of its elements being mucous and part serous. This muco-salivary secretion contains ptyalin, but not in the same proportion as the secretion of the parotid.

**The sublingual gland** is located, as its name implies, under the tongue, and opens by a number of small ducts (Rivini) on the floor of the mouth, one larger duct called the duct of Bartholini joining the sub-maxillary duct. This is strictly a mucous gland and furnishes a strongly alkaline fluid rich in mucin, but containing no ptyalin.

**The mucous glands** are scattered over the entire buccal surface, tongue and lips, and vary from the size of a pins-head to that of a pea. Like the larger sublingual gland, they secrete a product called mucinogen which is converted into mucin, the chief constituent of mucus, but they secrete no ptyalin.

**The saliva**, as we find it, is the mixed product of all of these glands. It is a viscid alkaline fluid containing about .5 per cent. of solid matter and having a specific gravity of about 1008. The chief organic constituents of saliva are mucin and the ferment ptyalin, while as morphological elements it bears salivary corpuscles.



Uepithelial debris and bacteria of many kinds. The amount secreted daily varies exceedingly, ranging from a half to three or more pints.

**Nerve supply of the salivary glands.** The usual impulses that excite these glands to action are sent from the nerve terminals located in the mucous membrane of the tongue, buccal wall and pharynx. The afferent fibres that call for this reflex run in the glossopharyngeal (chorda-tympani?) and the lingual and buccal branches of the fifth cranial; the centre for salivary secretion probably lying in the nucleus of the former. The efferent impulses to these glands follow separate routes, one being through the sympathetic and the other through a cranial nerve. The sympathetic gives to the gland secretory and vaso-constrictor fibres, while the cranial furnishes secretory and vaso-inhibitory fibres. The *parotid* gland receives fibres from the glossopharyngeal through the otic ganglion and (probably) from the carotid plexus of the sympathetic. The submaxillary and sub lingual each receive fibres from the chorda tympani (thirteenth cranial) and from the internal maxillary plexus of the sympathetic. As the stimulation of the sympathetic calls for secretion with a poor blood supply, the resulting saliva, called "sympathetic saliva," is thick and scanty, being overloaded with solids; while the stimulation of the chorda tympani, producing dilation with secretion, gives as "chorda saliva," a thin and watery, but abundant output. Central influences as well as gastric irritation will produce a reflex flow of saliva, as evidenced by the "watering of the mouth" when agreeable viands are smelled, and the flow of saliva that precedes vomiting. The various nerve connections of these glands seem to exert an inhibitory influence on them, for when cut off from all nerve control they begin and secrete continuously a

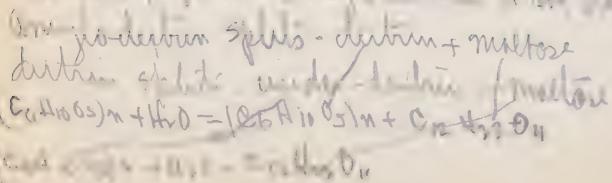


"paralytic saliva," till atrophic changes set in from exhaustion. *Atropia* paralyzes the secretory terminals in the glands but does not influence the vaso-motor terminals, so that we may get, on stimulating the chorda a vaso-dilation of the vessels in the gland, but no saliva.

The changes in the gland cells during rest and during secretion are most marked. These changes to a certain extent occur in all glands, salivary and otherwise, but the process differs with the gland. In the *serous or true salivary glands* the granular protoplasm accumulates in cells during the period of rest, and the cells swell until they almost obliterate the lumen. After a period of activity the cells are smaller and the small amount of granular matter left is found next the lumen, the remainder being clear. In the *mucous glands* the cells during the period of rest become filled with clear mucigen, which presses the protoplasmic elements and nucleus aside. During activity the mucigen is converted into mucin and discharged, and the cell becomes smaller.

**The chemistry of insalivation.** The amylolytic or diastasic ferment *ptyalin*, in an alkaline medium such as the mouth, changes starch into sugar. It does this by causing the starch to take up water and hence this action is also called a hydro-lytic action. The starch grains to be acted upon have an external envelope of *cellulose* and internal to this is the *granulose* or true starch. Unless this envelope be broken by either crushing or boiling, the ferment can not act on the starch. The resulting product of this diastasic action is the sugar maltose and dextrin, a starch which is converted into maltose later.

This power of converting starch into sugar is not limited to the animal ferments, as we find that the



remains unchanged  
H<sub>2</sub>O + dextrin present  
which is soluble  
maltose

↓ Red stop action of phosgene

vegetable ferment "diastase," as found in germinating barley and other cereals, possess the same powers. Being equally efficacious and much cheaper commercial diastase and malts entirely displace ptyalin in therapy.

**Deglutition.** After the fluid saliva has been mixed in with the food, softening it and otherwise acting upon it, there arises, from experience, a sense of being "ready," and we voluntarily "swallow." We must not suppose from this seeming control of the act that deglutition is voluntary; only the first step is voluntary, and that only so long as we have some food, saliva, or other substance in the mouth wherewith to excite the reflex.

The *voluntary* part of the process is performed by the lingualis muscle or tongue, and is as follows: The tongue is formed into a scoop, and taking the food upon its upper surface it forces it against the roof of the mouth where it is moulded into an oval bolus. The tip of the tongue is now turned up in front of the bolus, and its upper longitudinal fibres contracting, it is drawn back, bringing the food against the pillars of the fauces, and the reflex to complete the act is thereby excited.

The *involuntary* or reflex part of the act is an elaborate effort, and is produced as follows: The substance carried back by the tongue is brought in contact with the sensory terminals of the palatine nerves in the pillars of the fauces and soft palate. These are stimulated and send an *afferent* impulse up through the spheno-palatine ganglia and middle root of the fifth, to the centre in the medulla. The reflex *efferent* impulses are sent out through the pharyngeal branches of the vagus to the palato-glossus and palato-pharyngeus, and through the facial by way of the (vidian) spheno-palatine ganglia to the muscles of the soft



palate. The above group of muscles now contract and narrow the isthmus of the fauces (sphincter) from before backward. As the bolus of food touches the post-pharyngeal wall it excites a reflex (entirely through the vagus) for the contraction of the pharyngeal constrictors, and these respond in order from above down, the pressure of the food in the lower causing the action of the upper, etc. In precisely the same way it traverses the oesophagus, till at the cardiac orifice of the stomach the contraction wave of the oesophagus merges into the movements of the stomach.

At the instant at which the faucial reflex was excited, elevators of the larynx were stimulated to draw that organ upward under the base of tongue, thus turning the epiglottis down and over the rima glottidis. The glosso-pharyngeal terminals also stimulated at the same instant inhibit the respiratory function till swallowing is completed.

*The oesophagus* is the part of the alimentary canal that lies between the pharynx and stomach. It consists of four coats: a thin external fibrous coat; a muscular coat, containing an outer longitudinal and an inner circular layer; a submucous and a mucous layer. The muscular fibres are striated above, and gradually become non-striated below, where they continue on as the muscular fibres of the stomach. Squamous epithelium lines this tube and mucous glands open freely on its surface.

**II. Stomach digestion.** This includes all digestive processes taking place between the cardiac and pyloric orifices of the stomach.

**The stomach**, the principal organ of digestion, is a fusiform sac, curved on itself, and holding when reasonably full about two quarts.

It consists of four coats, arranged as follows: an



internal or mucous coat, a submucous coat, a muscular coat, and a serous or endothelial coat.

(1) *The mucous coat* consists of a delicate connective tissue reticulum thrown into folds and pits, covered throughout with columnar epithelium (goblet cells) on a basement membrane, and supporting glands of several kinds, blood vessels, lymphatics and *muscularis mucosae*.

These glands are of two kinds, one found chiefly in the cardiac end of the stomach or fundus, and called "fundus glands," and the other in the pyloric end of the stomach, called "pyloric glands."

*The fundus or peptic glands* are multiple tubular glands, and, within the basement membrane below the short duct, we have two kinds of cells, central and parietal.

The *central cells* are believed to be the source of the special ferment of the stomach, *pepsin*, which is here secreted as *pepsinogen* and afterwards converted into the above. The function of the *parietal cells*, often improperly called peptic cells, will be considered later.

*The pyloric or mucous glands*, not so abundant as the foregoing, are confined to the pyloric end of the stomach, and are continuous through the pyloric orifice with Brunner's glands in the duodenum. The lumen of the ducts and tubes is quite large, and lined with a cubical epithelium that corresponds to the central cells of the fundus glands. They secrete mucus and possibly some ferment.

The *muscularis mucosae* encircles by circular and longitudinal fibres the deeper parts of these glands, and by periodic contractions empties them of their contents.

Blood vessels run into the honey-comb like processes of mucous membrane between the glands, and lym-



phatics encircle the tubes of the glands and their necks.

(2) *The sub-mucous coat.* An areolar reticulum lying below the mucous coat and containing the larger vessels which supply the glands and interglandular folds with capillaries, lymphatics, &c. Adenoid bodies are found especially in the pyloric region. Meisner's plexus of nerves is found here, whose function is the control of the glandular secretions of the stomach.

(3) *The muscular coat* consists of longitudinal fibres, continuous with those of the oesophagus and intestine, and circular fibres, found within the former. On the fundus the inner circular fibres are irregularly disposed in figure 8 loops, hence termed oblique. Between the outer and inner muscular layers we have Auerbach's plexus of nerves, whose function is the control of the peristaltic movements of the stomach.

(4) *The serous coat.* A serous endothelium covering the surface at nearly all points. Under it lie the superficial lymphatics.

**The nerves of the stomach.** The right vagus supplies the post. surface and the left the anterior. The splanchnics of the sympathetic also give it a free supply. The function of these nerves seems to be one of *regulation* only, for while the ganglia of the stomach (Auerbach's and Meisner's) seem able to carry on its movements and secretions properly, the stimulation of the vagus intensifies both these acts, and the stimulation of the sympathetic inhibits both. The vagus is probably the bearer of vaso-dilator, and the sympathetic of vaso-constrictor impulses. The emotions seem capable of influencing digestion through either channel.

**Mechanism of stomach digestion.** When a bolus of food is received into the stomach at the cardiac orifice,



the mechanical impact stimulates Auerbach's plexus of nerves and excites the muscular coat to action. By progressive peristaltic movements the bolus is carried along the greater curvature to the pylorus, and thence along the lesser curvature back to the cardiac opening. This grinding, churning movement of the organ is repeated until the food is disintegrated into a grumous mass of broken down material called "chyme." During all this period the pyloric orifice is closed, and it does not open till the more solid parts of the food are broken down and softened.

*10-15 fls  
per day*

**The gastric secretion.** The gastric juice is an almost clear, colorless fluid, of acid reaction and a specific gravity of 1002-8. It is secreted at the rate of from 12 to 15 pints daily in man. It contains the ferment pepsin as its chief organic constituent, a peculiar milk-curdling ferment called rennin, and free  $\text{HCl}$  to the amount of .2 per cent. In addition, we usually find lactic and butyric acids, with salts of lime, soda, potash, etc. No satisfactory explanation of the presence of this  $\text{HCl}$  has yet been given. It is undoubtedly formed from the  $\text{NaCl}$  of the blood for the blood becomes more alkaline after its secretion but further than this we know little. It is thought by some to be formed through the dissociating influence of the parietal cells of the fundus glands but this is very doubtful. It seems to disappear in carcinoma of the stomach. (tropeolin test.)

**Chemistry of stomach digestion.** The function of the gastric juice in digestion is to convert the colloidal proteid foods into crystallloid, and consequently absorbable, peptones. This is done after the following manner. When a proteid food is exposed under the proper conditions of temperature, etc., to the action of  $\text{HCl}$  it is gradually changed into a substance called



*then peptones - then peptones*

*acid albumin.* This acid albumin is acted upon by the ferment *pepsin*, and after a series of intermediate changes is converted into *peptone*. This elaborate process is but one of hydration, the peptones as we saw (page 56) being the hydrides of the albumins, and their action is really a hydrolytic action. The essentials to this action are a proper temperature, (98.6—100 F.) an acid medium, the mechanical disintegration of the tissues by the teeth and stomach movements, and the removal of the products of digestion as formed.

**Absorption in the stomach.** The numerous capillaries that ramify in the interglandular folds of the mucous membrane of the stomach rapidly absorb the water, salts, sugar, &c., introduced, and also the sugar and peptones formed in the stomach. The lymphatics aid to a certain extent in absorption.

**III. Intestinal digestion.** The processes here involved extend from the pyloric end of the stomach to the rectum inclusive. The anatomical parts brought into play are the duodenum and (jejunum) ileum of the small intestines, and the colon with its various parts, and the rectum, of the large. We consider here also the glandular appendages of the intestines, both intrinsic and extrinsic. The intrinsic glands are those in the intestine, as Brunner's glands, crypts of Lieberkühn, &c., while the extrinsic glands are the pancreas and liver.

The small intestine consists of the same four coats we had in the stomach, and Meissner's and Auerbach's plexus of nerves continue as above. The muscular coat here has no "oblique" layer, simple circular fibres being internal to the longitudinal. In the duodenum, just beyond the pylorus, the mucous layer of the gut is thrown into high ridges or folds, called *valvulae conniventes*, which extend around the inner

Curdling of milk = Coagulation

Chymotrypsin - Insoluble  
+ whey protein - Soluble for intake

face of the gut throughout the small intestine. They are most pronounced at the openings of the ducts of the extrinsic glands, and disappear near the ileo-cœcal valve. We also find throughout the small intestine minute tit-like projections upon the mucous membrane, called *villi*. These villi are found on the valvulae conniventes and other parts of the surface, down to the ilio-cœcal valve, and are covered like all parts of the intestine with columnar epithelium. This epithelium has a peculiar "rodded" appearance, and rests upon a basement membrane. Within this membrane ramify loops of capillaries, and within these is an open lymph space, from which a lymph radicle leads to the lacteals of the mesentery. Circular and longitudinal fibres of visceral muscle (*muscularis mucosae*) surround the lymph space and force its contents out at intervals. *Brunner's glands*, near the pylorus, are structurally and functionally much like the pyloric glands of the stomach. The other intrinsic glands of the intestine are the glands or *crypts*, of *Lieberkühn*. These are small tubular follicles located on the mucous surface between the villi, and sinking down into the submucosa. They are lined with (secretory) columnar cells, resting on a basement membrane around which is a plexus of blood vessels. These follicles, unlike the villi, are found not only in the small intestine but also in the large, almost down to the anus. As we saw (page 110) the solitary lymph nodes are found throughout the intestines, while Peyer's "glands" are found in the ileum only.

**The pancreas** discharges its secretion into the intestine a few inches below the pylorus by a duct which is fed by other ducts in its substance. Structurally it is somewhat like the true salivary glands, but softer in texture, its capsule being extremely delicate.



It is fully supplied with blood vessels, lymphatics and nerves, pacinnian corpuscles also being often found in its substance.

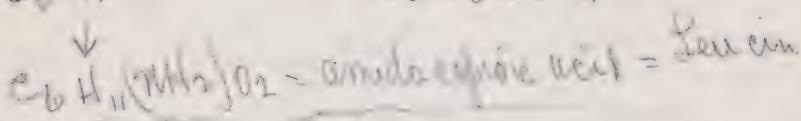
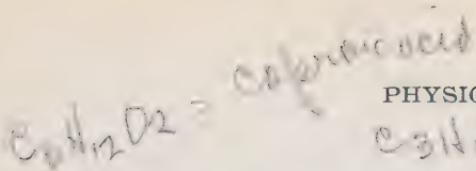
*Pancreatic juice* may be obtained from a pancreatic fistula. It is a colorless, transparent, slightly viscid fluid of alkaline reaction, and a specific gravity of about 1012. It contains three digestive ferments, trypsin, ~~amylopsin~~, and ~~steapsin~~, ~~alpha~~ milk-curdling ferment, some proteid matters and traces of the aromatic acids leucin and tyrosin. The ferment *trypsin* has in an alkaline medium an action analogous to pepsin, converting proteids into peptones. This ferment is formed in the pancreas as trypsinogen or zymogen. *Amylopsin* is a ferment very closely resembling ptyalin in its action on starches, &c. The other ferment, *steapsin*, has no analogue among the enzymes, being in some animals a fat-splitting "ferment," which causes the fatty acids to separate from their glycerin base. In man, as in all animals, its aids in the emulsification of fats, and in this assists the alkaline fluids of the intestine.

*The automatic secretion* of the pancreas, and, as we shall also see, of the liver, is probably due to intrinsic ganglionic nerve cells. These local centres receive impulses from terminals in the intestine (Meissner's) when digestion is excited by the presence of food. The "regulation" of these extrinsic glands is probably under the care of the vagus and sympathetic as above.

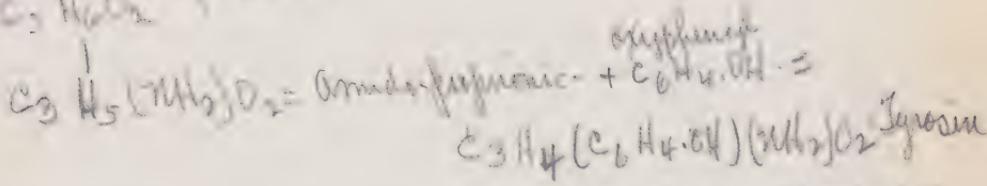
**The liver** is the largest gland in the body. It consists of an external serous layer, and underneath this is a fibrous capsule, called the "capsule of Glisson." On the under side of the liver, where the great vessels enter, the capsule turns into the substance of the gland and dividing into various planes forms the framework. The various fibrous planes of these internal septa.

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$C_3H_6O_2$  is formed



End products formed by fermentation of proteins upon proteolysis  
Lactic acid |  
Isopropanol |

joining with the trabeculae from the peripheral capsule, divide the liver into small spaces called *lobules*. The nutrient artery of the liver is the *hepatic artery*, which entering at the fissure follows the capsule in its various divisions and nourishes all its parts. The blood of the *portal vein*, rich in the products of absorption, enters the liver and also follows the planes of internal septa, giving off small veinlets which run in the capsule between the lobules, and are called *interlobular veins*. From these veins *capillaries* pass in toward the centre of the lobule to join a system of veins which run more or less at right angles to the interlobular veins, and these are called *intralobular veins*. Their blood is gathered into larger veins, often called *sublobular*, and uniting, as the *hepatic veins*, joins the inferior vena cava. The hepatic veins also carry the blood of the hepatic artery. In each lobule of the liver, and lying around the capillaries that lead from the inter- to the intralobular veins, are found the glandular cells of the liver. They are packed so closely around the capillaries that the border of each cell is grooved by the vessel. The sides of the cells that lie in contact with each other also contain grooves which, fitting into each other, form tubular channels between the cells. Into these "inter-cellular channels" the bile secreted by the cells is discharged, and being gathered into larger ducts leaves the liver by the hepatic duct. This hepatic duct, after giving off a diverticulum to the gall bladder, the cystic duct, is continued on to the intestine as the common bile duct.

*Ant. 150-1000 C. 1008-10  
1008-10  
April 16 1930-250*

The bile in man is an orange-colored fluid, of sweetish bitter taste, having an alkaline reaction and a specific gravity of 1025 to 1030. It contains : the bile salts before considered, glyco-cholate and tauro-cholate of soda ; the bile pigment bilirubin, isomeric with



haematoxin and probably derived in this form from the haemoglobin liberated in the spleen; mucus derived from the mucous glands in the gall bladder; a mild diastatic ferment; cholesterol, &c., &c. Human bile on being exposed to the air or an oxidizing agent turns green from the oxidation of the bilirubin into biliverdin.

*The secretion of bile* is constantly taking place, but is increased after the ingestion of food. The bile secreted during the interval between meals is stored up in the gall bladder, to be emptied by reflex muscular contraction of the bladder walls, excited by food in the intestine. This reflex may be intensified by duodenal irritants, and most of the so-called "chologogues" act simply by emptying the gall bladder (calomel). It is a curious fact that the secretion of bile is carried on with a "secretory force" that is greater than the force of the blood pressure in the capillaries of the liver. If, therefore, any obstruction occurs in the bile duct which prevents the outflow of the secreted bile, the force of secretion will cause it to pass into the contiguous blood vessels producing "jaundice" or icterus.

*The function of the bile* is that both of a secretion and an excretion. As a *secretion* it acts: (1) on the mucous coat of the gut as a stimulus to peristalsis; (2) both by reason of its alkalinity, and by its special properties it aids in emulsifying the fats; (3) it influences the absorptive power of the columnar cells of the villi, and (4) it is a mild antiseptic. As an *excretion*, it carries off with it the products of katabolic metabolism in the blood, &c. This is most marked in foetal life, where in spite of an empty intestinal tract, the bile is formed as regularly as after digestion begins.

*The glycogenic function of the liver* is the term applied to the power it has of forming glycogen, or

*Unsoluble in Bile*  $\text{Na}_2\text{CO}_3$   
 $\text{Na}_2\text{PO}_4$



animal starch, from the maltose absorbed from the intestines. The sugar absorbed is carried to the liver by the portal vein, and as it passes through the capillaries it is brought under the influence of the liver cells and converted into glycogen, which is largely stored up in the liver. That the liver can, under certain conditions, reconvert this starch into maltose is shown by the experiment of Bernard as follows: Some time after a full meal remove the livers from two animals. By injecting water into the portal vein wash all the blood out of each. Cut into small pieces and dip the pieces of one into boiling water to kill all ferments, but leave the other unboiled. If tested some hours later the boiled liver will contain no sugar, but glycogen, while the liver in which the diastasic ferment was not killed will contain much sugar but no glycogen. How or where this glycogen is used is uncertain.

*Glycosuria* or diabetes mellitus is due to free sugar in the systemic vessels and its elimination by the kidney. While a much disputed point, it seems caused by some vaso-motor disturbance of the vessels of the liver, which so interferes with the proper conversion of maltose that it passes on unchanged into the general circuit. Injury of the vaso-motor centre, of the greater splanchnic or of the sympathetic ganglia in or near the pancreas will produce it.

**The large intestine.** This gut shows the same four coats that we have in the small intestine and stomach, but in several of them changes of importance occur. The longitudinal fibres of the muscular coat are here gathered into bands whose length is less than that of the other coats, and this produces in the gut the sacculated folds peculiar to this intestine. This puckered appearance of the gut extends from the appendix to the lower part of the sigmoid flexure, where the fibres of the three



longitudinal bands spread out to surround the gut as in the small intestine. No valvulae conniventes, no villi, and but few lymph nodes are found in this gut, and no glands except the follicles of Lieberkuhn, which are abundant. The *rectum*, while larger, has the same general structure as the small intestine. In its upper part several valve-like folds of mucous membrane are found, (sphincter of Hyrtle) and in its lower the circular fibres are developed into a thick internal band, forming the *sphincter ani*. The fibres of the muscularis mucosae inordinately developed here give the appearance of an internal longitudinal layer. Striated muscular fibres radiating from the margin of the anus form the *corrugator ani*, or so-called "external sphincter."

**The succus entericus.** This term applies to the secretion of the intrinsic intestinal glands, but as the secretion of the glands of Brunner is relatively insignificant, in practice it applies to the secretion from the crypts of Lieberkuhn, mixed in with mucus from the goblet cells. Its secretion seems to result from the same nerve stimuli as the glands above. No special ferments have been found in it but it has several important functions, seemingly as follows: (1) it has a slight diastasic action on starch, forming maltose; (2) it can convert or "invert" cane sugar (saccharose) into dextrose, and (3) it has a feeble peptonising power. This latter action it is well to note, as it suggests artificial digestion for the proteids of nutrient enemata.

**Chemistry of intestinal digestion.** The *starchy forms* of carbohydrate food which escape the action of the ptyalin in mouth digestion undergo but slight change in the acid medium of the stomach, but when the alkaline region beyond the pyloric orifice is reached the ptyalin seems again to begin its diastasic action. At the same time these starchy food stuffs are brought



under the action of the more powerful diastasic ferment amylopsin, which in this medium rapidly converts the remaining starch into sugar. How this is done is not well understood. Amylopsin and the diastasic ferment of the succus probably convert dextrin into maltose, while the sugar, (saccharose) is reverted by the ferments of the succus entericus alone. The *proteid forms* of food which have escaped the action of the pepsin in the stomach, or at least have been but partly acted upon, are here again subjected to the action of a proteid ferment, trypsin. This ferment in an alkaline medium converts proteids into peptones, under the following conditions: The proteids which had been converted in the stomach into acid albumen, are now precipitated by the alkaline media in which they find themselves. These precipitated albumens and other (untouched) proteids are converted into alkali albumens, and these being acted upon by the trypsin are converted into peptones. The continued action of trypsin upon the peptones it has formed (hemi-peptones) produces a variety of nitrogenous compounds, chief among which are leucin, tyrosin, and various acids. The *fatty food-stuffs* which in the stomach were unaffected by its juices, other than to have their proteid support dissolved, are now modified in various ways. In the presence of the alkaline fluids, especially the bile, these liberated fat globules break up into a fine emulsion, in which form, as we shall see, they are capable of being absorbed. Some of the fats, in the presence of the fat-splitting ferment steapsin, probably break up into glycerin and their corresponding fatty acids. These acids, in turn, become saponified by the alkalies of the intestine. Both soaps and emulsion are capable of absorption, but in different ways.



**Putrefactive phenomena in the intestines.** Swallowed with the food, fluids and air are many bacteria, as we saw in the saliva. Many of these are the peculiar bacteria that produce fermentation and putrefaction, and in the lower intestine their action upon the products of proteid digestion yields a variety of putrefaction products, among which are the foul-smelling material that gives to human faeces its characteristic odor, together with indol or indican ( $C_8H_7N$ ), skatol ( $C_9H_{11}N$ ), phenol ( $C_6H_5O$ ), &c. These processes, together with the fermentation of carbohydrates, are accompanied by the evolution of gas. Among the gases found as the result of these decompositions are  $H$ ,  $CO_2$ ,  $CH_4$ , and  $H_2S$  in small quantities. These gases in quantity produce distension and colic, especially in infants. In hysteria and other neuroses gas may be formed in the stomach at a rate that seems to preclude the idea of fermentation alone, and suggests dissociation. The putrefactive processes, especially with proteid foods, may give rise to highly toxic products, suggesting in their action the ptomaines. (auto-intoxication.)

**Absorption in the intestines.** The water and mineral food stuffs are absorbed as easily as in the stomach. The starchy parts of the carbohydrate food are after conversion into sugar (maltose) readily absorbed by the blood vessels of the villi and mucous membrane. The peptones, the results of proteid digestion, are absorbed as in the stomach by the capillaries, but wherever absorbed they seem to be reconverted into proteids (serum albumen) in the process of absorption. The fats, when emulsified (not saponified,) are absorbed by the peculiar columnar epithelium covering the villi. The globules seem to be taken into the bodies of these cells and discharged into the lymph space of the villus, whence, by the periodic contractions



of the muscular fibres, they are forced into the lacteals (chyle). Most of the gastric and intestinal juices of secretion are reabsorbed, and bile is in large measure reabsorbed to return to the liver. Whenever, owing to obstruction or imperfect muscular action, the decomposition products are retained for a long time in the canal, they are in a large measure also absorbed. Some of these produce the faecal odor observed in such cases, and indican may appear in the urine at such times in appreciable amounts.

**Mechanism of intestinal movements.** The normal movements of the intestine are dependent upon the stimulation of Auerbach's plexus. This stimulation produces contraction waves (peristalsis) from the upper toward the lower parts. The presence of the intestinal contents, bile, etc., furnishes the normal stimulus, but it may be modified by many conditions. The amount of fluid in the gut influences peristalsis, (saline purgatives) excitement of its local ganglia aids it (strychnin), irritation of the mucous membrane also powerfully excites it (croton oil, etc.) paralysis of the inhibiting terminals of the sympathetic allows it freer action (atropin), while stimulation of the inhibiting centres check it (opium).

**Muscular and nerve mechanism of defæcation.** Peristaltic movements carry the faecal masses along the large intestine until they reach the lower part of the sigmoid flexure. Here it seems as if their presence ceases to act as a stimulus to the gut, and that the folds of the mucous membrane in this region mechanically prevents their descent. When, however, this region becomes full and distended with faeces, the pressure induces a desire to go to stool. This desire is brought about by nerve terminals in the gut wall, which send impulses to the centre of control. This



centre, called the *ano-spinal centre*, lies in the lumbar cord. It is in a tonic state of activity, keeping the sphincter ani tightly closed, but such impulses as those above increase its tone and the intensity of its impulses to the sphincter. There is a portion of the gut, however, in the lower rectum called the "sensitive rectum," the stimulation of which by faecal matter not only causes relaxation of the sphincter, but increases powerfully peristalsis above. When an action is desired, man seeks his accustomed place and making forced (voluntary) abdominal pressure aids the peristaltic movements in forcing the faecal matter down until it touches the sensitive rectum. Here the sensitive portion of the gut is stimulated and an impulse is sent to the *ano-spinal centre* causing a reflex inhibition of the sphincters below. These sphincters may also be voluntarily inhibited when desired. Peristaltic and voluntary muscular forces then press the mass onward through the patulous opening below. As it tends to drag the gut onward with it in its descent, this is overcome by the muscularis muscosae and levator ani drawing the gut and perineum upward over the mass, and the sphincter closes behind it. The corrugator ani by alternate contraction and relaxation then frees the anus of adherent faecal matter. We may by the will "silence" these calls to the defaecation centre until the terminals in the gut become functionally almost inactive, and constipation and dilation, with all attendant evils, result.

**Time occupied in digestion.** Peristalsis begins in a few minutes after food has been introduced into the stomach, and continues there for a period of about five hours. The chyme remains in the small intestine about three hours, and the excretory matter in the large intestine usually about twelve hours.



**Vomiting and its mechanism.** The *vomiting centre* lies upon the floor of the fourth ventricle, near the nucleus of the tenth nerve. It may be stimulated reflexly by *afferent* impulses from : the stomach (10th); the soft palate, circumvallate papillae, pharynx, &c., (9th) ; the uterine nerves (pregnancy); the intestinal tract, hernia, invagination, &c., (mesenteric nerves) ; the ureter and kidney, (least splanchnic); the gall duct and liver (splanchnic); the lungs in phthisis (10th). The centre may act under impulses from the sensorium, stimulated through the nerves of sight, hearing, taste and smell. It may be stimulated directly by drugs, or the terminals in the stomach may be stimulated. The act is ushered in by an undefinable feeling of nausea, perspiration may occur, and a rush of saliva to the mouth (chorda). Then a deep inspiration, to lower the diaphragm, is taken and the glottis closed. In this condition the abdominal muscles make a powerful expiratory movement, compressing the stomach and its contents against the lowered diaphragm. At the same time the pyloric orifice being closed and the cardiac aperture opened the contents of the stomach are forced out through the oesophagus and mouth. The young infant vomits chiefly by the contraction efforts of the stomach itself, and hence they bring up no bile. With adults the first effort empties the gall bladder into the duodenum, and continued efforts bring some of it into the stomach and thence up ("biliaryness" ?). The application of ice over the larynx (sup. laryngeal of vagus) will often inhibit vomiting.

**The administration of ferments**, prepared from the digestive appendages of lower animals, is of much value in various forms of atonic dyspepsia. The artificial diastase obtained from "malt" supplements the action of ptyalin and amylase. Pepsin, pre-



pared chiefly from the stomach of the hog, is of much service. The administration of dilute H Cl is also of decided benefit in certain cases.

**Post-mortem digestion** of the stomach wall, and even of contiguous organs, sometimes occurs. Why this is not done during life is not understood, but is probably due to the protective influence of the alkaline blood circulating in its walls.

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## CHAPTER VIII.

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### THE SKIN AND ITS FUNCTIONS.

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**The skin** of the human body shows a surface of from 14 to 18 square feet. It is histologically an extremely complex structure, its varied elements giving evidence of its manifold functions. It varies in thickness not only on the different parts of the body, but in the different races—climate, attention and environment producing marked changes in this respect. The skin may be divided into two layers, which separate readily on blistering, maceration or decomposition. The superficial layer is called the *epidermis or cuticle*, while the internal or true skin is called the *derma or corium*.

**The epidermis** is a relatively thin layer overlying the true skin, but which becomes much thickened in the parts exposed to habitual pressure, as the heel, soles of the feet and palms of the hands. In the various flexures it is thinner than on the general body surface (inunction), but on the eyelids, lips, glans penis, female genitals and external auditory canal it is extremely thin.



(infection atria). It consists of four layers from without in, as follows : (1) The *stratum corneum*, a thin layer of flat, horny scales, which have lost their nuclear constituents and other resemblance to cells, and are now chiefly keratin. (2) The *stratum lucidum*, more or less flat squamous cells, the superficial layers of which are keratinous. (3) The *stratum granulosum*, much similar in shape to the layer above, but containing granules of eleidin. (4) The *stratum malpighi*, or *rete mucosum*. This layer is as thick as all the preceding layers combined, and while its external face is parallel with the layers above, its inner face follows the contour line of the papillæ of the corium, alternately rising over and dipping between them. The malpighian layer consists of first an external layer of "prickle cells" whose ridges do not interlock but simply touch, and secondly a layer of very long columnar-like cells which lie parallel but have no cement substance between them. This layer is pigmented (melanin) in the darker-skinned white races and in the negro ; all the layers in the latter race are more or less dark. The open spaces of this layer allows the percolation of lymph to the *stratum granulosum* unchecked. Nerve fibres also run in the *stratum malpighi* almost up to the granular layer. The superficial horny scales are being cast off from the surface at all times, and are renewed by the proliferation of cells in the *rete mucosum* which are moved up to take their place, degenerating as they go.

**The corium**, derma or *cutis vera* is the thick dense layer of the skin lying below the epidermis. Its upper surface is raised into tit-like processes or *papillæ*, made up of dense fibrous tissue intermingled with elastic fibres. Below this is a more open reticulum of much similar tissue, and this in turn is continuous below with the subcutaneous areolar tissue. The space



between the skin and the muscles, &c., is filled in, even in the lean, with adipose tissue or fat. This is especially true of women, and gives the rounded contour peculiar to this sex. There is no fat beneath the skin of the genitals, eyelids or upper parts of the ear. *The papillæ* are of variable size, some of the larger having smaller papillæ springing from their apices. These are called compound papillæ. On the palms of hands and soles of the feet these papillæ are arranged in rows, forming lines and fissures of great complexity, but usually symmetrical on the two halves of the body. In many of the papillæ, especially of the fingers, may be found the complex nerve terminals called touch corpuscles. Throughout the derma, but particularly near the hairs, may be found scattered non-striated muscle fibres whose contraction puckers the skin, giving the so-called "cutis anserina." The blood vessels of the skin are derived from branches of the deeper vessels which make toward the surface. As they pass up they give off branches to the masses of fat cells that lie in the areolar layer, then to the sweat and sebaceous glands, and finally end in minute capillary loops in the papillæ of the corium. From these exudes the lymph that supplies the epidermal tissues.

**The epidermal appendages** are the *hair* and the *nails*. These are composed of the same modified keratinous cells that form the horny layer on the general surface of the skin.

*The hair* is an elongated column of keratinous tissue (debased cells) which grows from a papilla sunk deep in the true skin. It is composed of an imbricated external envelope, then the cortex or hair substance, and in this a core or medulla of more or less pigmented polyhedral cells. The *hair follicle* is composed of



many layers, of which we will only say that all internal to the hyaline membrane are epidermal, and all external are from the corium, the membrane itself being derived from the thin but dense portion of the connective tissue that forms the surface of the papillæ. The presence of this epidermal tissue deep in the substance of the skin is of great importance in the regeneration and repair of superficial injuries (epidermization). From the base of each hair follicle there passes obliquely upward a bundle of non-striated muscle fibres, the erector pili muscle. These in times of fear or emotion make "each particular hair to stand on end" and by post-mortem contraction give rise to the tales of growth of hair after death. The hairs are of three varieties: (1) The *long hairs*, found on the scalp, genitals, and armpits of both sexes, and on the face and to a variable extent the breast and general body-surface of males. (2) The *stiff hairs*, as the vibrissæ of the nostrils, the eyelashes of the lids and the eyebrows. (3) The *downy hairs* found on the general body surface, and sometimes in the caruncula lachrymalis. Hairs are found on all parts of the body except the palms of the hand and the soles of the feet, the exposed mucous membranes, eyelids, and last phalanx of the extremities. Straight hair is usually round on cross section, curly hair oval and woolly hair flat. Gray hair is usually produced by imperfect formation of the internal pigment, but sudden blanching is produced by the vacuolation of the shaft by gas. The *lanugo* or downy hair of foetal life is shed entirely by the time the child is six months old. Diseases of general malnutrition produce falling of the hair, termed alopecia (fever, syphilis, etc.).

*The nails* are, as it were, compound hairs. They grow from the matrix rapidly, but as a very thin layer,



which thickens as it progresses by growth from the long rows of proliferating papillæ over which it moves. The spots often seen on the nails are due to vacuolation, but parasitic diseases may alter the structure (onychomycosis) and general diseases, as syphilis, may cause shedding of the nails as of the hairs (onychia). An ingrowing nail is always produced by the pressure of the adjacent toe raising the flesh up over the nail-groove.

**The glands of the skin** are both secretory and excretory in function. The *secretory* glands, those that produce something needed by the body (or its offspring), are the sweat glands, mammary glands and the sebaceous glands with their modifications. The *excretory* glands, those which remove something not formed in the gland and detrimental to the body, are the upper parts of the sudoriparous or sweat glands.

**The mammary glands** are two large hemispherical eminences or *mammae* located upon the lateral aspect of the pectoralis major muscle. Undeveloped accessory mammae are sometimes found located in a line down the breast below the others, in the axilla or even on the shoulder. The mamma presents at the centre of its convexity a smaller conical eminence, the nipple or *mammilla*. This tit or nipple is composed of areolar tissue, surrounded with circular and radiating plain muscular fibres (erection) pierced by fifteen or twenty milk-bearing or *lactiferous ducts*. These ducts expand at the base of the nipple into larger cavities or *ampullæ*. The skin of the nipple is, in the virgin, of a pinkish brown, and surrounded by a zone or *areola* of rosy tint. In pregnancy this areola begins to darken about the second month, and continues to darken and widen till at the full term it is in brunettes almost black, and twice the previous diameter. The base and sides of the nipple are set with sebaceous glands, and often misplaced lactiferous ducts open on its sides or



base. If we follow the lactiferous ducts we will see that they radiate from the nipple into the substance of the mamma, that they receive ducts as we follow them, and the ultimate ducts come from lobules of glandular elements that secrete the milk. The acini of these glands contain short columnar secretory cells. During the periods between pregnancy the ends of these cells next the lumen undergo fatty degeneration and break off into the cavity forming *colostrum* corpuscles. It is this rich unctuous matter that the child gets when first nursing, and it acts as a very desirable purgative to empty its bowels of meconium, &c. The third or fourth day after labor the secretion of true milk begins, but oil globules still form in the cells and are extruded, forming the cream. The interstices between the lobules are filled in with fat, and the whole structure supported by fibrous tissue intermingled with plain muscular elements which aid in the expulsion of the milk. The blood supply of this gland is abundant and varied, coming from the axillary, intercostal and internal mammary arteries. The lymph ducts are numerous, and follow the lower border of the pectoralis major to the axilla, being beset with many lymphatic glands (carcinoma). The nerves are, strange to say, all from the cerebro-spinal system.

**Human milk** is a thin bluish white fluid of quite sweet taste and sp. gr. of 1030. When first drawn milk is faintly alkaline, soon becomes neutral and then slightly acid. A "good mother" secretes daily from two and a half to three pints. The comparative analysis with cow's milk below gives its general chemical peculiarities :

(Per cent.)	Fats.	Casein.	Lactose.	Salts.	Water.
Human milk,	2.5	2	5	.5	90
Cow's milk,	4	4	4	1	87

We can see from the above why water should be



added to cow's milk. The proteids of milk are casein and lact-albumen.

The casein exists in milk as caseinogen, seemingly an alkali albumen, which is (precipitated) coagulated by acids or special ferments, and converted into casein. The ordinary "souring" of milk is due to the formation of lactic acid from lactose, (lime water), under the influence of the wide spread ferment, *bacterium lactis*. The fats are in the form of an emulsion, cream. The chief salts are basic phosphate of calcium, chlorides of soda and potash, traces of iron, etc.

*The sebaceous glands* are either single or multiple racemose glands, whose saculi are filled with columnar cells which do not really secrete, but, like the mammary cells during the inactive stage, undergo fatty degeneration. These fatty cells are discharged into the large ducts of the glands forming an oily unctuous mass, the *sebum* which keeps the skin soft. Sometimes these glands have ducts of their own, but usually one or more of them open into the necks of the hair follicles. These glands are only absent from the plantar surfaces of the feet, and palmar surfaces of the hands, being most abundant on the hairy parts and the regions around the various openings of the body. This sebum appears at the open orifices of the ducts, being pushed out by the proliferation of the fat cells behind. As these orifices are darkened by dirt, they receive the common name of "black heads" and are properly called *comedones*. There is a parasite (*demodex folliculorum*) found in them at times, but not always. When these duct mouths become closed we have the large sebaceous retention-cysts found on the back, behind the ears, &c. On the female genitals and under the prepuce in man we have a modified form of sebaceous gland which gives the secretion peculiar to these parts.



**The sudoriparous or sweat glands.** These have two distinct functions, the one *secretion* of sweat, and the other the *excretion* of  $\text{CO}_2$  and other deleterious matter. The structure of a sweat gland shows this variation in function. These glands are scattered over almost the entire body. They are absent only from the glans penis and prepuce, are scanty on the back, while abundant on the face, hands, feet and flexures. They consist of long tubular glands, of two distinct parts, having separate functions. The deeper is the *glandular* portion, and the superficial the *respiratory* portion. The coiled or glandular portion of the tube ("glomerulus") is deep in the subcutaneous areolar tissue. It consists of a basement membrane and single layer of long spheroidal epithelium. A plexus of capillaries surrounds the coil, with lymphatics, nerves, &c. The upper or respiratory part of the tube makes its way in a spiral or corkscrew-like manner through the epidermis to open by a mouth on the surface. It is lined by several layers of small cubical cells whose lumen surface is covered by a delicate membrane.

**Sweat and its secretion.** The sweat is an almost colorless fluid, containing about one per cent. of solid matter, and is usually alkaline. It contains, besides a volatile oil,  $\text{CO}_2$  and a little urea. The relative proportion of solids and gases varies greatly in exercise, disease, &c. The amount secreted per diem varies with the climate, race, individual, state of health and muscular activity. Broadly stated it varies from one to three pints of fluid daily, with traces of the volatile fatty acids, that give the peculiar racial odors, and the amount of  $\text{CO}_2$  given on page 156. A reciprocal action exists between the function of the skin and the kidneys. In the moist, cool climate of England the amount of perspiration is small and the urinary secretion is large,



while on the dry plains of the southwestern United States the urinary secretion is small and the action of the skin very great. The secretion is under the control of a centre and special set of nerves. The dominating centre is in the medulla, and like all medullary centres is bilateral. Subordinate centres are in the cord. Impulses from this centre seem to follow the routes pursued by the vaso-motor impulses. Central stimulation may be produced by emotion, super-heated blood, venous blood, or by drugs (nicotin). Some drugs act both centrally and on the peripheral secretory nerves (pilocarpine). Reflex stimulation is usually produced by increase of temperature, in the air and surroundings (hot-air bath). The secretion of sweat may be checked by paralyzing the terminals of the secretory nerves (atropine) or by the application of moist surface cold.

**The functions of the skin** as based upon the foregoing studies lead us to note: (1) It is a *protective covering* for the body, impermeable to ordinary chemical poisons, bacteria and other forms of virus, when its horny layers are unbroken; (2) It is a *poor radiator* of body heat when dry. Any interference with its natural surface, as a burn of large superficial area, or varnishing the skin, produces serious depression of temperature. The subcutaneous layer of fat is a most valuable non-conductor of heat; and when by the contraction of the muscles of the skin and vaso-motor constriction of its vessels the blood is gotten behind this barrier, man is in his best state of protection against cold; (3) Its power of *lowering body heat* by the action of its glandular elements, the sweat glands, and the subsequent evaporation of the sweat from the surface of the body. The full influence of this lowering is gotten by dilating the superficial



capillaries and thus exposing the blood to be cooled as it passes ; (4) It aids in the *excretion* of the deleterious products of metabolism, and while this is relatively small it may be made use of to aid vicariously other organs (uremia) ; (5) It contains the *terminals* for most of the *somatic senses*. The end organs of touch, temperature, &c., are all in the skin. The presence of the temperature terminals in the skin causes them to play a peculiar part in what we call a "chill." When from any internal congestion, as pneumonia, pleurisy or the essential fevers, the vaso-motor centre to maintain pressure cuts off the supply of blood to the skin, and the muscles of the skin contract, we have the cold, "creeping" sensations of a chill and probably a rigor. This is due to the fact that the temperature terminals in the skin, which are usually kept warm by the hot blood circulating around them, are now deprived of this warmth, and although the rectal temperature may be several degrees above normal, the patient shivers ; (6) (Notwithstanding its powers of resistance, the skin possesses some small capacity for *absorption*. This is especially true of the oils and fats, which are more readily absorbed than other substances. This power is of use in the administration of drugs in the form of ointments, by rubbing them into the soft skin of the flexures (inunction).

**Pathological lesions of the skin** dependent on its internal structure are many, among which we will note the following : *A blister* is produced by any agency that will cause a pronounced and continued congestion of the capillaries of the skin, to the extent that the effusion or exudate poured out from the vessels lifts the epidermis or scarf skin from the corium. The effect of this on the system is first the one derived from the extraction of this amount of fluid (blood) from adjacent



parts, and secondly the effect produced by it on the large number of nerve terminals which it necessarily affects. A blister may be produced by heat; by the vesicants, as cantharides, &c., and by the so-called rubefacients if their action is prolonged, in fact by anything that fulfills the conditions above given. As intra-capillary pressure is essential to the formation of a blister, this lesion is of medico-legal value in proving the existence of life. *A vesicle* is essentially but a small blister, and all the "vesicular" diseases from eczema to pemphigus are produced by the same conditions. To go further whenever the *local* congestion of the capillaries is only sufficient to produce a change of color in the skin it produces a *macule*, but when sufficiently pronounced to cause a local infiltration of the tissues, and an elevation above the normal skin level we call it a *papule*. It is only when the congestion is both pronounced and continued that it produces an outpouring sufficient to create a local cyst or *vesicle*. If chemical or bacterial agencies add their action and pus forms in the vesicle we have a *pustule*. This epitome of local action gives as we see a brief outline of the usual "types" of skin disease. The exciting cause in these cases is probably local (eruptions), although central vaso-motor disturbance may cause dilation of the vessels and exudation. Parasites, as the female *acarus scabiei*, may produce vesicles and hatch young in them. *Warts* of the skin and mucous membrane are but hypertrophied papillæ, "moles" being pigmented forms of the same. *Freckles* are caused by the grouping of pigment cells in the superficial layers of the stratum malpighi under the influence of the sun's rays.



## CHAPTER IX.

## THE KIDNEY AND ITS FUNCTIONS.

The two organs that bear the above name are placed on the posterior wall of the abdomen, and are purely excretory in their functions. It is their province to remove from the blood the waste products of tissue metabolism and also those products of absorption which play no part in the constructive processes of the body.

**The kidney**, while covered by the peritoneum in front, has no serous covering except in one of the forms of the rare condition called "floating kidney." The external coat of the kidney is a *fibrous capsule* joined loosely to the tissues below by connective tissue fibres. This capsule covers the entire surface and dips down into and lines the cavity (sinus) on the concave side of the organ. A longitudinal section of the kidney shows it to consist of two parts: An external or *cortical part* lying next to the capsule on the convex side, and an internal or *medullary part* lying within the former and opening by a series of pyramidal projections into the sinus. These pyramids of malpighi, as they are called, have their basis next the cortex, and where these join we have a distinct boundary line called the cortico-medullary line. The supporting *framework* of the kidney is most dense in the capsule, next in the apices of the pyramids, and after this in the boundary layer, or zone of the medulla next the cortico-medullary line. In the cortex the framework is loose and open, a *reticulum* of fibrillar elements filled in with the *parenchyma* of the gland. The muscular elements of the



kidney (visceral) are found as a thin investing layer under the capsule, as a ring of fibres around the apex of each of the malpighian pyramids, and in the walls of the blood vessels, except the *vasa recta*.

**Vessels of the kidneys.** *The arteries.* The renal artery, usually single, breaks up into from four to six branches called the *arteriae propriæ renæ*, which pass up between the pyramids to the cortico-medullary line, where they divide and follow this line as the *cortico-medullary* or *arcuate* arteries. They give off (1) cortical branches called the *interlobular* arteries which furnish the *vasa-afferentia* and *glomerulus* (and *vasa efferentia*) and also the *terminal* arteries of the subcapsular plexus. The vessels which leave the *glomerulus*, called the *vasa-afferentia*, and ramify around the *uriniferous tubule*, especially the convoluted parts, help to form the *interlobular plexus*. (2) The medullary branches which run straight down into the pyramids, are called the *arteriæ rectæ*, all end in the *pyramidal plexus*. *The veins.* The blood from the sub-capsular plexus and from the plexus around the convoluted tubule (*interlobular plexus*) unite to form the *interlobular veins*. These join vessels lying in the cortico-medullary plane called *cortico-medullary veins*. These *cortico-medullary veins* also receive the blood of the *venæ rectæ* coming from the medullary side and emptying the *pyramidal plexus*. There is an anastomosis between the plexus of the convoluted tubule and the *pyramidal plexus*. The blood of the *vasæ efferentiae* nearest the cortico-medullary line is divided, part going as above to form the *interlobular plexus* and the remainder going straight down in a set of vessels called the *vasæ rectæ* which, crossing the cortico-medullary line, pour their blood into the *pyramidal plexus*. Observe the fact that should there be



an obstruction to the flow of the blood in the interlobular veins, the blood of the lower *vasa efferentia*, at least, can take a "short cut" through the *vasa rectae* to join the pyramidal plexus. Also observe the fact that the dilation of the terminal vessels of the interlobular arteries and the contraction of the *vasa afferentia* will allow the blood to pass through the subcapsular plexus and interlobular plexus to join the interlobular veins without passing through the glomerulus. *The lymphatics* are of two kinds, the superficial set running on the surface of the gland under the capsule, and the deeper or interlobular lymphatics in the substance of the cortex.

**The uriniferous tubule.** When the *vasae afferentiae* leave the interlobular arteries they curve upward as very small vessels which are twisted and coiled on themselves, forming ball-like plexuses, the *glomeruli*, from which the blood is carried by the outgoing vessels or *vasae efferentiae*. Around each *glomerulus* we have a delicate membrane of squamous cells which is reflected on itself to form the *capsule* (Bowman's) of the *glomerulus*, and from which leads the *neck* of the uriniferous tubule. This leads into the *proximal convoluted tubule*, having the same lumen but thick walls made of rod-beset epithelium. Becoming *spiral* the tube now dips down into the substance of the boundary layer and returns (*Henle's loop*) to about the same level. The epithelium of this part of the tube is thin, being composed of squamous plates set in a peculiar alternate manner. Becoming again *spiral* the tube *ascends* in the cortex to about the level from which it started, and turning in an *irregular* manner at a sharp angle it forms the *distal convoluted tubule*. This has a rod-beset epithelium almost identical with the proximal tube, and differs only from the irregular tube in



having the nucleus of its cells central. From this point the "glandular" functions cease, and the *collecting tubule* joins a *straight tube* which runs down in the pyramids and unites with a *discharging tube* which opens at the apex of the papilla in the calyx.

**Nerves of the kidney.** A dozen or more filaments supply the kidney. They are derived from the renal plexus, which receives branches from the great, and especially the lesser splanchnic divisions of the sympathetic. Each kidney is supplied by fibres from both sides of the sympathetic cord. These nerves supply the non-striated muscular fibres of the vessels, and sensation. No evidences of secretory nerves exist, the vaso motor impulses controlling the output. Ganglionic cells are found in the substance of the gland, and seem to have some control over the vaso-motor conditions independent of the vaso-motor centre.

**The secretion of urine.** There are two distinct stages in the formation of urine, from the blood entering the *vasa-afferentia*. As the blood flows rapidly from the more or less straight vessels into the closely coiled glomerulus, friction and peripheral resistance cause a rise in intraglomerular blood-pressure. This results in the filtration of *water* through the glomerular walls into its investing capsule. As the blood, now in concentrated form, leaves the glomerulus by the *vasa efferentia*, it is carried through the plexus of capillaries surrounding, and in intimate relationship with, the rod-beset epithelium of the convoluted tubules. Here the *salts* and specific urinary constituents are extracted from the blood by the special action of the epithelium cells of the tubules, and are removed by the water flowing within them. When we consider that in the lumen of the *uriniferous tubule* we have nearly pure water, and in the capillaries surrounding



the tube a more or less concentrated saline solution, we might call this latter exchange osmosis. It is not, however, a purely physical process, but the vital action of the tubular epithelium is involved in this elimination, and that of the glomerular epithelium in the "filtration." If partly or purely an osmosis, a proportionate amount of water must be absorbed from the tubule for salts, etc., going in. Heidenhain demonstrated the above as follows: He injected into the blood of a dog a solution of sulph-indigotate of soda, a blue pigment, and waiting till it began to appear in the urine, killed the dog. An examination showed the cells of the convoluted tubules filled with the pigment granules and stained blue, while the epithelium of the glomerulus was not stained. If the above theory be true, a rise of blood pressure in the renal artery should give an increase in the amount of urine, and we find that the urine does increase pari passu with the blood pressure.

**Physical characters of urine.** It is a mobile, amber-colored fluid, normally of slight acid reaction, with a specific gravity varying from 1010 to 1025. The average adult male secretes about 35 or 40 ounces in 24 hours in this climate. It has a characteristic odor and taste. As modifying its physical character we may note: Increased quantities of salt, even the pathological constituents, sugar and albumen, may make it less mobile and give it a tendency to froth when shaken. The urinary pigments which give color to urine vary but little in health, hence the marked color variations found depend chiefly upon the amount of water with which they are diluted. Ordinarily varying from light to dark amber, in disease and toxæmia it may range from the water white of diabetes and hysteria to the yellow of santonin, red of senna, red-brown of bile,



brown of rhubarb up to the black of phenol poisoning. The acid reaction of fresh urine becomes alkaline on standing, especially if in a warm place. The administration of alkaline or earthy bases or their carbonates, etc., renders the urine less acid or alkaline, while the administration of acids, especially benzoic acid, makes it pronouncedly acid (page 64). The variation in the amount secreted (as seen under variations in color) gives the normal variations in specific gravity; but only disease gives the extreme limits of range, as hysteria and diabetes insipidus 1001-4, and diabetes mellitus 1030-40. The variations in quantity range from absolute suppression to 8 and even 12 quarts daily in diabetes. The odor varies from the characteristic odor of fresh urine to the putrescent ammoniacal smell of the old article. The administration of various essential oils and balsams make it highly aromatic, other drugs, as valerian, asafoetida, etc., also give their characteristic odor. Old diabetic (mellitus) urine is sour, while fresh has a sweet odor.

**Constituents of urine.** Normal urine contains about 96 per cent. of water and 4 per cent. of solid matter. About two-thirds of the solid matter is organic, the remaining one-third inorganic. The chief organic constituent is urea, and the chief inorganic sodium chloride.

*Urea*, ( $\text{CO}(\text{NH}_2)_2$ ) the diamide of  $\text{CO}_2$ , is the chief end product of the oxidation of the nitrogenous constituents of the body. It represents about one-half of the solid constituents of the urine, being about 2 per cent. About one ounce is excreted daily by an adult. It is isomeric with cyanate of ammonia, and may be formed artificially. The amount of urea is increased by an increase of proteid food, by hastening nitrogenous tissue-metabolism, and also to a less extent by



increasing the general urinary output. When we consider the necessity of O in maintaining the stability of the complex proteid constituents of the body, we will see why in dyspnoea and other conditions of imperfect oxidation it is increased. Starvation diminishes it to about one-fifth, where it remains fixed till death. In fever the amount is increased till the crisis, and then falls. While we know that it is not formed in the kidney, we are not absolutely assured of the point of formation, unless it be the liver. The decomposition of urea and water into carbonate of ammonia takes place on standing, and may take place in the bladder in the presence of certain micro-organisms, as the *micrococcus ureae* (page 62).

*Uric Acid* ( $C_5H_4N_4O_3$ ) is, next to urea, the substance that represents the N eliminated. The amount eliminated is about 10 grains daily, making the ratio of urea to uric acid about 48 to 1. It is seldom or never eliminated as free acid, but combined with soda (or potash) as a salt. To obtain it free add HCl to urine, or keep in a cool place till acid fermentation begins. It appears in brick-red rhombic crystals of various forms. In birds, reptiles and insects it represents almost the total output of N eliminated. In the urine of herbivora it is small in amount or absent, and a vegetable diet decreases the amount formed in man. The amount is increased in man by severe physical exercise, rheumatism, leukaemia, and digestive troubles. In gout there is reduced elimination rather than increased formation. The salts of uric acid vary greatly in solubility, lithium salts being most soluble, potash salts next, soda next, and ammonia least.

*Urinary pigments, &c.* There is much doubt as to which special pigment can be called the pigment of normal urine. Urobilin is present in the urine of



fevers and to a certain extent in normal urine. Urochrome, uroerythrin and uromelanin all occur in varying quantities and conditions, but all are derivatives of the bile pigment bilirubin, in its turn a derivative of the coloring matter of the blood. Kreatinin, formed by the dehydration of the kreatin of muscle, is a nitrogenous body occurring in about the same quantity in urine as uric acid. Oxalic acid combined with a calcium base is of variable occurrence in human urine. (calculi).

*Inorganic constituents of urine.* The quantity of inorganic salts is usually not great, seldom exceeding one-half oz. daily. They may be taken in in the same form in which they are eliminated, but you must remember that the phosphates and sulphates, &c., may be formed by oxidation of the P and S of the food. Sodium chloride is the most abundant, varying with the amount eaten, &c. In certain diseases it is markedly diminished, as in pneumonia and various effusions. Two kinds of phosphatic salts occur. (1) The phosphates of the alkalies. These may be acid sodic phosphate or acid potassic phosphate. It is to these acid salts, especially the former, that we owe the acidity of the urine. (2) The earthy phosphates. These are the acid phosphates of lime and magnesia. They have the peculiar property of being precipitated by heat, which the alkaline phosphates have not. Sulphuric acid occurs in the urine in two forms. The most usual is that in which it is united with alkalies to form salts. The other is the union of sulphuric acid with certain aromatic ether bases, indol, skatol, etc., to form definite compounds.

**Conditions influencing output of urine, salts, etc.** Increase of the total *contents* of the vascular system increases blood pressure and consequently the output



of urine, as copious drinking, intravenous injection, etc., while decrease of vascular contents diminishes it, as profuse sweating, bleeding, etc. Increase in the *capacity* of the vascular system, as by dilation of superficial vessels from warmth, etc., diminishes blood-pressure and the output of urine ; while decrease of vascular capacity, as by the influence of cold, constricting vessels of skin, etc., increases pressure and urine. Variations in blood pressure brought about by the vaso-motor centre directly act in the same way. Increased action of the heart, with increased force, produces greater output of urine, and conversely feebleness of heart or valvular disease gives the reverse.

**Effects of retention of excretory products.** The retention of urea in the blood gives rise to a special form of toxæmia known as *uraæmia*, and the retention of uric acid produces a condition known as *lithæmia*. *Uremia* is rapidly fatal when pronounced, but if the suppression of the activities of the kidney is temporary, or only partial, stimulation of the vicarious action of the skin and bowels often checks the convulsions and tides the patient over. *Lithæmia* is due to a deficient alkalinity of the blood, and not to the excessive formation of uric acid. Uric acid is very insoluble, but as we saw, its salts are more readily held in solution. The excessive and improper use of the starches, sugars, malt and spirituous liquors, is apt to produce acid dyspepsia, the lactic, butyric and other products of which, being absorbed, negative the normal alkalinity of the blood, and produce retention of uric acid and often deposit in the tissues. Gout, rheumatism, cystic, and nephritic calculi, or the peculiar general nervous symptoms of retention are apt to occur.



**Diuretics and their influence.** Some diuretics, as digitalis and its class, produce diuresis by increasing the force of the heart's action and general rise of pressure. The nitrite class of diuretics, where they act at all, act by causing a dilation of the vessels of the kidney. Still others, as the alkaline type of diuretics, while not well understood, seem to produce their result by their endosmotic influence on the filtering and secretory tissues of the kidney. The class of stimulating diuretics, which are usually essential oils, (as juniper,) stimulate the secretory and possibly the filtration elements.

**Abnormal constituents of urine.** *Albumen.* The most important clinically of the abnormal constituents of urine is albumen. It is derived from the serum albumen of the blood and may be more or less mixed with serum globulin. The appearance of albumen in perceptible quantities in the urine is indicative of disease. The presence of albumen may indicate either organic disease of the glomerular or tubular epithelium (nephritis) or marked increase of intra-glomerular blood pressure. If the latter condition be the cause and it be transient, no organic disease may result. (Physiological albuminuria?) Other temporary causes of albuminuria are proteinid plethora, the exanthemata (scarlatina), renal irritation by drugs, pregnancy, etc.

**Tests for albumen.** Heller's test. Pour one-half inch of urine into a test-tube, and then holding the tube obliquely pour in about an equal quantity of  $HNO_3$ , which by reason of its density will settle down under the urine. If albumen be present, where the two zones meet will be formed a white ring of precipitated albumen. Care is necessary not to mistake copaiba, acid urates, etc., for albumen. Heat test: Place an inch or more of clear urine in a test-tube and



apply heat to the upper part slowly. If albumen be present it will be indicated by a whitish coagulum forming in the urine. This may vary from only a cloud to a dense mass, according to quantity. Earthy phosphates, if present in quantity, will be precipitated in a similar manner, but require more heat. If ten or twelve drops of  $HNO_3$  be added to the urine containing the precipitate, and it be albumen, no change will take place, but if the precipitate be earthy phosphates, it will disappear. This test is not as good as the preceding.

*Sugar* is next to albumen the most important abnormal constituent of urine. When large quantities of grape sugar are taken into the body we find a temporary glycosuria, but it is only when the output of sugar is habitual, as from disturbance of the vaso-motor supply of the liver, that we have true diabetes mellitus. In this disease the output of urine is largely increased as well as the sugar. This seems to be due to a stimulation of the secretory elements of the kidney by the sugar in the blood, as lactose administered in large quantity will produce the same result. In mellituria or diabetes mellitus the sugar may run as high as 12 to 15 per cent.

*Tests for sugar.* Indigo-carmine test : A solution of indigo-carmine made alkaline with sodic carbonate, when boiled with diabetic urine changes from blue to violet, then red, and finally to a straw color. As the solution cools it will, if shaken, give these colors in the reverse order. The urine should be added, drop by drop, as the test is delicate. Fehling's or Pavy's test : To 20 drops of Fehling's solution add four times its bulk of water, and boil for a few seconds. Add urine drop by drop, and if any great amount of sugar be present we will get the orange-yellow precipitate of



cupric oxide. If we get no precipitate from the first few drops, continue to add urine, heating occasionally, till a volume is added equal to the original solution. If we get no precipitate, sugar is absent. This test may be applied to determine the amount of sugar quantitatively. *Blood* may be found in the urine (haematuria) coming either from the kidney, as in malarial fevers, or from the urinary tract. Urine containing blood is, of course, always albuminous. *Bile* may be found in the urine (choluria), being eliminated from the blood by this channel, but evidence of its presence is presented in other ways, as jaundice.

**Deposits in urine.** These may be either organized or unorganized, pathological or normal. *Organized deposits.* (1) *Mucus.* This is found to a slight extent in nearly all urine, as a flocculent cloud at the bottom of the vessel. (2) *Pus cells.* In urine they closely resemble white blood corpuscles and indicate inflammation of the kidney or tract. Acetic acid will resolve their nuclei. Caustic potash added to pus sediment makes it viscid and ropy. (3) *Spermatozoa* may sometimes be found, usually after intercourse. (Spermatorrhoea?) (4) *Bacteria* of various kinds, but not in *normal* urine. (5) *Tube casts.* These are of vast diagnostic value. They are formed by the plasma, which by reason of pathological conditions has come through the walls of the glomerulus. It coagulates in the uriniferous tubule, and may be forced onward presenting simply the mould of the tube (hyaline casts). The pathological condition may be accompanied by exfoliation of the epithelium of the tubule (epithelial casts) or by the outpouring of blood (bloody casts) or by the formation of pus (purulent casts). The forced passage of these casts often breaks them into small granular masses, held in place by continued coagula-



tion around them (granular casts). (It should however be noted that epithelium shed by the tubes in catarrhal states may at times be pressed into form and moulded into casts without fibrin; and that the same is true of amorphous urates.) (6) The various forms of epithelium from the urinary tract, with dirt, cotton and wool fibres, etc.

*Unorganized deposits.* These may be amorphous, as urates, calcium phosphate, etc., or crystalline, as uric acid, calcium oxalate, triple phosphate, ammonium urate, etc.

**The urinary tract.** *The ureter.* Beginning with the calices, which open into the pelvis, it narrows into a small tube which extends to the bladder and pierces the wall of that viscus obliquely, forming a perfect valve. On section it shows three coats, an external fibrous, a middle muscular (non-striated) which is in its turn formed of three layers, and an internal mucous coat. The muscular coats consist of a thick external longitudinal, a middle circular and internal longitudinal, best developed in the last inch that pierces the bladder wall. The mucous coat (transitional) contains in its sub-mucosa some adenoid and mucous glands. The nerves of the ureter are derived from the mesenteric and spermatic plexus. (This anatomical relation explains why in cases of nephritic colic we so frequently have the pain reflexly referred to the testicle or to the glans penis.) While gravity no doubt aids, the movement of the urine is due, primarily, to the action of the muscular coat of the ureter. Beginning in the sphincter of the papillæ it is excited reflexly downward (nephritic calculi). This action of the ureters is claimed to be alternate. The nerve supply of the ureter is associated with that of the sphincter



urethrae as the writer has often seen the passage of a sound relieve a paroxysm of nephritic colic.

*The bladder* is a hollow viscus, the reservoir for the urine, normally holding about a pint, but capable of infinite distension. The walls are composed of three complete coats, the mucous (transitional), sub-mucous and muscular. The latter is very irregular in its arrangement (*detrusor urinæ*). The interior of the empty bladder is thrown into numerous folds or *rugæ*. The mucous coat is freely movable on the muscular except at the *trigonum vesicæ*. The prostate gland which encircles the neck of the bladder is a very peculiar body, composed of mixed muscular (*sphincter*) and glandular elements. It is pierced by the urethra and ejaculatory ducts, and contains the *sinus pocularis* (*uterus masculinus*). The nerves of the bladder are from the fourth sacral and sympathetic, and numerous ganglia are located in the mucous and muscular coats. The lymphatic and vascular supply are abundant, the latter being from the three vesical arteries (*urachus*) in the male, and the uterine and vaginal, in addition, in the female.

*The urethra in the female* has a purely urinary function, in the male it is more complex, serving genito-urinary purposes. In the female it is made up of muscular, erectile and mucous coats from without in, and is lined with squamous and transitional epithelium. It is capable of great dilation. The *male* urethra is divided into a prostatic, membranous and spongy portion. The first is lined like the bladder, of which it is a part, with transitional epithelium. It is quite dilatable, and of horse-shoe shape on section. The membranous urethra is surrounded by the *compressor urethræ* (*striated*) muscle, and is lined with a columnar-like epithelium. In the spongy portion we



find it as before of nearly uniform size except just behind the meatus, where it expands into the fossa navicularis. The meatus is lined with squamous epithelium. At the fossa navicularis there is a change in the axis of the urethra, its long axis passing from a horizontal to a vertical position as at the meatus. The prostatic glands discharge their thin milky acid secretion into this canal, as do also Cowper's glands, and the numerous mucous glands (Littré) along the tract (gleet). The secretion of the first is chiefly at the time of coitus, forming no small part of the seminal fluid. It is also a peculiar fact that while the spermatozoa are virile while in the seminal vesicles their power of active motion is not attained till in the act of ejaculation they are mixed with prostatic or other urethral fluids.

**Mechanical and nerve mechanism of micturition.** As the bladder becomes distended by the increase of urine, no nervous impulses are generated until the bladder becomes almost full. (Adult, 16-18 oz.) As this condition is reached, impulses originating in the sensory terminals of the bladder wall are sent out. Some of these go to the sensorium, and the indescribable sensation of a full bladder is experienced. Others go to the urino-spinal centre of the cord, and there excite reflexly periodic motor impulses to the muscles of the bladder and to the sphincter urethræ. These offset each other for a time, but in the end the power of the bladder will overcome, and a few drops of urine will be forced past the sphincter into the sensitive part of the urethra. Sensory impulses starting here reflexly excite in the lumbar centre inhibitory impulses to the sphincter and it relaxes, while the bladder is still stimulated and the urine flows freely. This is the process in the child or infant. With experience man learns to voluntarily inhibit the tonic impulses to the



sphincter and to initiate the act by the use of the abdominal muscles. The influences of fear, &c., markedly affect this centre through the cerebrum. So also does suggestion, as seeing another urinate, the sound of falling water, etc. The emotion of modesty or shame is a powerful inhibitor. While the normal healthy bladder is uninfluenced by the presence of urine, unless in large amount, any excess of acidity is quickly irritating (alkalies) & when markedly irritated normal urine will excite the bladder to action even when in small amount (*hyoscymus*).

**Changes in urine after expulsion.** When fresh urine is set away in a cool place, with time it becomes more and more acid. This is called the *acid* fermentation of urine. It seems to depend upon a special fungus of little known character, and partly, perhaps, upon the influence of mucus in normal urine. It results in the formation of free uric acid, and an increase of acid sodium urate, calcium oxalate, etc. This freeing of the uric acid is probably due to the formation of lactic and acetic acids, by the decomposition of certain organic constituents (mucus) of urine. When urine is kept still longer, especially in a warm place, *alkaline* fermentation takes place. This is evidenced by its reaction and ammoniacal odor. The agent is the micro-organism (*micrococcus urae*) which causes the urea to take up water and form carbonate of ammonia. The same & kindred organisms when introduced into the bladder, as by a dirty catheter, will cause there the same ammoniacal decomposition. This is particularly true of the bladders of elderly men in whom changes in the prostate prevent the complete emptying of this viscus (*henzoic acid*).



## CHAPTER X.

## METABOLIC PHENOMENA.

The term **metabolism** includes that series of phenomena by which all living organisms incorporate the substances obtained from their foodstuffs into their tissues, and make them into integral parts of their own bodies. Thus a store of potential energy is formed, which can, in accordance with the needs of the organism, be converted into kinetic energy, as muscular force, heat, etc. These changes in the constituents of the tissues result in the formation of excretory products, which is but another part of the process of metabolism. The normal process of metabolism then requires : a supply of food qualitatively and quantitatively suitable, the assimilation and incorporation of this food in the body, a regular transformation of tissue constituents in the body, the formation of waste products and their elimination from the body by their proper channels. The constructive part of this process is called anabolic metabolism, the destructive part katabolic metabolism. Of the functions, that of digestion is distinctly anabolic, while that of urinary excretion is preeminently katabolic, and respiration divides its honors.

**An analysis of metabolic processes.** There is in each human organism, in a state of health, a daily gain and a daily loss of body weight. *The gain* is obtained through (1) the lungs, from the O of the atmosphere (insignificant); (2) the digestive tract from food, i. e. proteids, carbo-hydrates, fats, salts and water. *The*

NaCl,  $10\%$  salt +  $10\%$  urea -  
amino-acids fatty acids

Glucose - in urine  
NaCl salt in urine - was removed

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Glucagon - pancreas, liver, heart, muscle

Insulin | Spleen - liver, muscle, urine, blood  
Hypoglycemia

Ure a acid

Adrenalin - muscle, blood, brain

Urea in Hypoglycemia

loss is through (1) the lungs,  $\text{CO}_2$  and water; (2) the kidneys, water, urea, uric acid, salts, etc.; (3) the skin, water, a very small amount of  $\text{CO}_2$ , and body emanations; (4) the bowel, water, insoluble salts, and residues of foods, etc. When the income exactly equals the expenditure (quantitatively) we have the state called *metabolic equilibrium*.

**Chemical comparison of foods and excretory products.** Leaving out of consideration water and salts, which are excreted almost unchanged, man's food consists of complex organic and yet but slightly oxidized bodies. (See formulae.) The excretory products on the other hand are such simple bodies as  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and Urea, which in its turn readily becomes  $\text{NH}_3$  and  $\text{CO}_2$ , etc. It will be seen from this, and what we know of interstitial respiration, that the excretory products are the indirect result of oxidation processes in the tissues. The oxidation of proteids gives as a result  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ , Urea, etc.; the oxidation of fats,  $\text{CO}_2$  and  $\text{H}_2\text{O}$ ; while the oxidation of carbohydrates gives  $\text{CO}_2$  alone, the H being already satisfied. The prime function of the *proteids* (albumins, etc.) taken in is to supply the materials for *reconstructing the cells* and protoplasmic elements which have undergone degeneration and death. We saw an example of this loss in the study of the epidermis. The body, as we saw, being incapable of forming albumen, no other food can take its place. The function of the *fats and carbohydrates* is by their oxidation to furnish the energy for maintaining the mechanical functions of circulation, respiration, etc., and also the *heat* necessary to maintain body temperature. It must be remembered that proteids contain all the constituents of the carbohydrates and fats, and can therefore take their place in the production of energy. This can only be

$C_6H_{12}O_6$

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

$(C_2H_5)_2O_2 \rightarrow$

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$C_5H_8N_4O_2S$

if cells in organized tissues

Na - liquid

Ca/phosphate/carbonate/bones

done at the cost of an enormous waste of proteid food and of serious injury to the digestive organs.

**The effects of starvation**, partial or complete, demonstrate these facts clearly. Any warm-blooded animal deprived of all food, but water, must in order to maintain body temperature, and the necessary amount of mechanical work, utilize the potential constituents of its own body, losing weight, day by day, until death occurs. Adults die when they lose four-tenths of body weight, young individuals die sooner. If water be not given, of course the time is greatly lessened. On a purely *flesh diet* man cannot subsist long. As we have seen, the normal proportion between the nitrogenous and non-nitrogenous foods is 1 to 3.5. In a flesh diet (lean beef) the proportion of nitrogenous material or proteids, to the carbohydrates and fats, is vastly in favor of the former as compared with the above. A healthy person excretes as  $\text{CO}_2$  through various channels 8 to 10 oz. of C daily and to obtain this from such a flesh diet he must eat 5lbs. of meat a day. The digestive organs are unequal to this task for any great length of time. On a purely *carbohydrate or fat diet* man will live but little longer than when on water alone. Fats, sugar, etc., cannot replace the protoplasmic elements of the tissues lost. Still it is seen that on a diet of fat, etc., individuals eliminate less urea than when starving absolutely. In this case it is seen that the carbohydrates, etc., are used for energy, and the draft is made on the body tissues only for the repair of the protoplasmic elements used. This albumen-sparing action of fats and carbohydrates is important, as a small quantity of either will greatly limit proteid metabolism. Carbohydrates will take the place of fats in food, but the amount must be larger, as 17 to 10; the former however are the more readily



oxidized. Fats may be formed from a proteid diet alone, but practically they are not so formed. In the wasting process of starvation, the tissues are not used equally. The fats are the first to go, and ultimately disappear absolutely. The muscles suffer the greatest actual loss, but not the greatest relative loss, except in the very corpulent. The nervous system loses almost nothing, the muscles, etc., being used to repair waste here. Note the relative prominence of the nervous structures in a cadaver where death has occurred from tuberculosis or other wasting disease.

**Corpulence and its prevention.** Corpulence is a disturbance of the metabolic processes evidenced by a pronounced tendency to the formation of adipose tissue. It is usually the result of an inherited tendency, begotten of free living with little physical exercise. This tendency in man is a misfortune, but among our domestic animals it is cultivated as a virtue. The ingestion of fat is not necessary to its production, as it is equally apt to result from carbohydrate food. This condition is not to be confused with fatty degenerations; the latter may occur among the lean and thin as well as among the fleshy.

**Growth and its limitations.** Growth is the result of a metabolic condition in which an amount of nutritive material is received by the organism sufficient not only for all its needs in the development of heat and mechanical work, but beyond this giving an excess to be used in the construction of body substance. The increment of gain (both in weight and stature) in the progress from childhood to adolescence is quite rapid at first, but declines year by year till it practically ceases at thirty and even before. The increase in the total weight of the average human organism from birth to full development is measured by the ratio 1 : 20,



while the increase of the abdominal viscera in the same period is in the ratio of 1:13. Thus we see that while the general mass of the tissues requiring nutrition has been increased twenty fold, the abdominal organs, which supply this nutritive material by absorption, have been increased but thirteen fold. In other words, if the needs of the organization in the way of expenditure had remained proportionately the same in infant and adult, the adult would be a loser in nutritive power by reason of a relative decrease in the capacity of his abdominal viscera. But in the way of expenditure the adult demands infinitely more, as will be seen by the following example: Take a child one meter high and let him grow to two meters. His height has doubled. If the general proportions of his figure remain the same, his strength, which is measured by the area of the cross section of his body and limbs (the square), will have quadrupled, but his weight will be eight times as great, as it increases with the cube. In other words, while his stature has doubled and his strength has increased four fold, his weight, to be sustained and moved, is eight times as great, and on a relative decrease in nutrition he has to exert eight times the energy previously required to overcome inertia and momentum. Constructed upon plans essentially similar, this shows why the child in early life has such an excess of nutritive material over what is required for his needs in energy, and why in man the limit is reached in which all is needed for energy and none can be spared for growth. There are other factors of limitation, as the increased work of the heart required in the larger body, etc., while still other factors are in favor of the growth of the child, as the immensely greater relative capacity of the lungs. The only point in which the child calls



for a relatively greater expenditure is in supplying heat for a relatively greater radiating surface of body.

**Heat, its sources, elimination, etc.** The maintenance of the body-temperature requires the almost uninterrupted evolution of kinetic energy in the form of heat. When the temperature of the surrounding media is greater than man's body temperature (98.6 F. or 37 C.), of course the evolution of heat is not required, but this state of affairs is relatively rare. In certain respects warm-blooded or homoiothermal animals differ greatly from the cold-blooded or poikilothermal forms. The former maintain their fixed temperature regardless of changes in the media around them, while the latter follow quite closely the changes in temperature of their surroundings. This difference in relation to body-heat produces marked variations in functional activities in warm and cold-blooded creatures under the same conditions of temperature. Cold in man and all warm-blooded animals increases not only heat production but a desire for bodily activity; while with the cold-blooded forms it not only decreases heat production but makes them torpid and sluggish. Conversely warmth makes sluggish all warm-blooded creatures, and excites to full activity the cold-blooded.

**An analysis of heat production in the body.** Heat is produced in the body by the transformation of the chemical constituents of the food that are endowed with great potential energy, into such substances as have little or none. The combustion of the C of the food into  $\text{CO}_2$ , the H into  $\text{H}_2\text{O}$ , etc., whereby heat is produced, forms the chief source. As O is the agent of combustion in all cases, there is the relation of cause and effect between the amount of O consumed and heat produced. As the muscles form the greater part of the tissues in which metabolism is active, they are the

heat loss -  
Skin -  $\frac{1}{\text{Conduction}}$   $\frac{1}{\text{Convection}}$   
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15 }  
30 } 60%  
35 } 271

Lungs { evap.  $16.0$   
Ventilating air

15 }  
2.5 } 17.5%

Urine

2.5 - 2.5 +  
100 - 54

Heat production

1. muscles.
2. glands
3. Central nervous system.

great centres of thermogenesis, and probably four-fifths of the body heat is produced by them. The larger secreting glands, as the liver, pancreas, etc., are also centres of marked heat production. Any chemical change in the constituents of the body, whereby the atoms pass into more stable positions and the available potential energy of the tissue is diminished, leads to heat formation. Certain physical processes are a source of heat, as the muscular action of the heart, it being confined with its resistance to the body. A certain part of such work as is transferred to external objects produces heat in the body, as friction, shock, etc. The chemical changes in the food above mentioned, if carried to the point of forming  $\text{CO}_2$ , etc., will give exactly the same number of heat units that the same food would give if burned in a furnace. The apparatus for measuring the heating power of foods is called a calorimeter. Water is usually placed around the central combustion chamber or animal chamber to absorb the heat, and the elevation in temperature of a known volume of water by a given amount of food can be accurately determined. Taken in as foods, 52 parts of fat, 100 parts of albumen, 114 of starch or 129 of sugar (maltose) will give the same amount of heat, i. e., they are isodynamic.

**Conditions influencing temperature of the body.** The greater the metabolism in a part the greater its heat. It is thus that the act of secretion produces heat, proved by the venous blood from a gland being warmer than its arterial blood, and the contraction of a muscle produces heat. As metabolism is decreased during hunger (starvation), we find the temperature lowered during this state, while the temperature rises during digestion.

The so-called daily variations are probably results of



the accumulating influence of meals and modifying influences of habit. Age and feeble constitution have a lowering tendency, and the loss of blood has a pronounced influence in lowering. Certain drugs, as alcohol and quinine, seem to render the tissues less free to undergo metabolic changes, and thus lower the temperature. Strychnin acts in a manner just the reverse, and thus tends to raise the temperature.

**The regulation of temperature.** To maintain the body temperature constant as we find it in health there must be some agencies in the body that contribute to its regulation. These agencies are the heat-producing (thermogenic), the heat discharging (thermolytic), and the heat balancing (thermotaxic). The last, functionally the highest, is only found in homioothermal animals, and is easily disturbed. Having considered the thermogenic agencies in the previous sections, and the thermolytic under the functions of the skin, we will only consider thermotaxic phenomena here. From what we learned of the skin we can see how the temporary application of moderate cold can excite the functions that raise the body-heat, and the application of heat excite, in a similar way, those that lower it. Cold in any great degree produces involuntary muscular movement (rigors, etc.) as well as a desire for voluntary muscular movements, both of which produce heat. Cold sends much of the blood to the deeper parts, oxidation is increased, and we breathe more rapidly to eliminate the  $\text{CO}_2$  formed, but the same movements supply the increased amount of  $\text{O}$  needed for combustion, and at the same time reduce the general temperature by evaporation from the lungs and the warming of the large amount of cold air used. The presence of heat produces the reverse of these processes. Cold always increases one's appetite for food, especially



fats ; in hot weather the reverse holds true, and if food is wanted it is not fat.

**Storage of heat, clothing, etc.** Warm clothing is the equivalent of food in that it saves the heat of the body, by preventing its radiation, and thus less food is burned to maintain the normal temperature. As small bodies have greater radiating surface in proportion to their bulk (measure of heat production), they must be more warmly clad than larger bodies for the same temperature. Thus we see why children need relatively warmer clothing than adults, and why they are dwarfed by exposure, being required to use for heat what should have gone for body-construction. Observe the influence of these laws on the workings of nature. Even in the tropics no small bird or animal is naked although the elephant, hippopotamus, rhinocerus and tapir are so found. In northern latitudes such an amount of food is needed for heat production that but little can be used for growth, giving such dwarfing as is found in the Shetland and Iceland ponies. In the selection of materials, their capacity for conduction (fur, wool, cotton, flax, silk,) for radiation (rough, smooth,) for absorption (black, dark, light), for permeability of air, etc., must be considered.

**Fever.** *Fever (pyrexia)* consists in a "disorder of the body-heat." The mechanism for the regulation of the balance of income and expenditure is disturbed. Little of the potential energy is transformed into mechanical work in this state, almost all being transformed into heat. Combustion in the body is vastly increased, giving rise to the wasting or "consumption" long observed. The excretion of  $\text{CO}_2$  is therefore vastly increased (60-80 per cent.); the elimination of urea also (30-60 per cent.), and the urinary pigments, potash salts, etc., likewise. But we must never forget the



difference between calorimetry and thermometry. For instance, fever may result from deficient heat elimination, with very slight increase in production and no serious injury to tissue, and yet the thermometer show pyrexia. On the contrary, if heat formation and elimination be both increased, with serious injury to the patient, the thermometer may show little or no rise. High temperature (hyper-pyrexia) shows such a marked thermotoxic disturbance as would lead us to believe that not only are the heat producing processes increased, but heat eliminating processes are diminished. High temperatures long continued will produce fatty atrophy of the tissues, as heart muscle, etc. (typhoid fever). Quinine, and perhaps alcohol, are almost the only drugs that act as antipyretics by alone preventing heat formation, most antipyretics, as antifebrin, antipyrin, phenacetin, etc., acting largely by increasing heat elimination, as well as by preventing heat formation.



## CHAPTER XI.

## THE CONTRACTILE TISSUES.

The simplest form of that shortening, which when exerted by masses of cells in a definite direction we call the contraction of muscles, is seen in the amoeba. It is also seen in white blood cells, salivary corpuscles, etc. It is however indefinite in direction in all of these. The *first evidence* of a tendency to *definite movement* is seen in the *cilia*, the vibrating hair-like processes seen on certain cells. They are more or less flattened appendages attached to the free ends of the cells, often as many as a score to each cell. They do not vibrate in unison, but a wave of movement travels from cilia, and across from cell to cell, at regular periods, many times a second. The amplitude of this vibration is  $20^{\circ}$ – $30^{\circ}$ , and the return is only one-half the speed of movement in the direction of its impulse. Under the influence of gentle heat they are stimulated to increased movement, while cold retards them. Anaesthetics, like ether and chloroform, produce a temporary palsy of their action, and opiates produce the same effect in less degree. Caution as to the use of opium in cough mixtures is necessary, especially with children. Much higher in the scale than these simple hair-like bodies we find the muscular tissues.

**Muscular tissues, their chemistry, etc.** The three forms of muscle fibre, striated, cardiac, and non-striated, all consist alike of protoplasmic contractile elements. The variations in structure seen histologically and the difference in time of action, nerve supply,



etc., are acquirements of late date, the internal substance being essentially the same. *Striated muscle* is the highest type, and it is of this form that most is known; being not only the most important and abundant, but being also voluntary, it is better suited for experiment. Of this form of muscle, as of the others, it may be said that the protoplasmic sarcous substance is as much a fluid as a solid. Taken in mass, muscle contains 75 per cent. water, and of the 25 per cent. of solids, 12 are proteids, while salts, extractives and fats form the remainder. From fresh disintegrated muscle we can express a faintly alkaline or neutral fluid, the muscle plasma, which spontaneously coagulates, forming myosin and an acid muscle serum (*rigor mortis*). Traces of a myosin ferment have been found. Striated muscle is very *elastic*, and recovers, if not overstretched, its original length almost completely. The increment of lengthening with an increasing load is a receding one; i. e., if the load of a muscle be repeatedly doubled it will not stretch to double the amount previously stretched, but less and less till it will no longer stretch at all. This elasticity is of service in giving quickness of action, as no time is lost in taking in slack when a muscle is stimulated to action. In excised muscle *electrical currents* may be detected with the galvanometer, having a definite direction and constancy. They are called the natural muscle currents in passive muscle. In such they are from the pole to the equator in the muscle and hence the reverse in direction in the conductors outside the muscle. Not only do they pass from pole to equator, but the point of lowest potential being at the centre of the polar section, and the highest at the periphery of the equatorial plane, intermediate currents can be seen of varying intensity. These currents are lessened by fatigue, and gradually



disappear with loss of vitality. To prevent the influence of polarization in these experiments, what are called non-polarizable electrodes must be used. These electrodes are usually made of glass tubing filled with a good conducting fluid and ending in a tip of porous clay that absorbs the fluid. Wires inserted into the fluid of the tubes connect with a delicate galvanometer.

**The active state of muscle.** A muscle has the power when properly stimulated, of passing from the passive elongated condition into one of contraction or activity. The degree of this capability is called its irritability, and the influences bringing it about are called *stimuli*. The various stimuli may be enumerated as follows: (1) The normal stimulation, such as we see in healthy muscles acting under the impulse of the will through the centres and nerves. (2) Electrical stimulation, produced by any variation in the intensity of an electric current when passing through a muscle. (3) Chemical stimuli are produced by the application of certain drugs to the cut end of a muscle, viz: mineral acids, many mineral salts, dilute glycerine, etc. (4) Mechanical stimulation may result from a pinch or blow, etc. (5) Thermic stimulation. If the temperature of a muscle be reduced, it will shorten before freezing; and if raised, it will begin to contract below body temperature and pass into a state of spasm (heat rigor) about  $124^{\circ}$  F. In experimenting the second method chiefly is used, the induced (Faradic) current being the most convenient.

**Changes in muscle on entering the active state.** The metabolic changes always taking place in passive muscle are markedly intensified in active muscle, and new chemical decompositions occur. The blood vessels are all dilated, the amount of O absorbed is increased,



and the  $\text{CO}_2$  excreted markedly raised. There is less glycogen and maltose in an active muscle than in a passive one, but muscles devoid of all these compounds will still respond to stimuli. At the same time these carbohydrates are habitually the chief source of muscular energy. An active muscle becomes acid in reaction, and its temperature is increased. It becomes less elastic during the active state, that is, a given weight will extend it more. The most marked change is in its electrical current. When a stimulus to action is applied through the muscle nerve, the natural current at once ceases. This is called the *negative variation* of the muscle current. It is shown with difficulty by the galvanometer, but if the nerve supplying another muscle be laid so that one point touches the pole and another the equator of the muscle stimulated, its negative variation acts (by induction) as a stimulus to the applied nerve, and excites a contraction in the muscle it supplies. (Rheoscopic frog.)

**Rigor Mortis.** Both striated and non-striated muscles at a variable time after death pass into a state of cadaveric rigidity or *rigor mortis*. The cause is the spontaneous coagulation of the myosin factors within the sarcolemma of the muscle fibre. During the process heat is formed and acid set free, as in active muscle. The onset varies from a few moments to seven hours, and lasts longer the later it begins. Violent muscular action before death hastens it. Its duration is usually from one to six days. It begins in the muscles of the jaw and extends downward, ceasing first where it began.

**Recording muscular contractions.** The apparatus used in recording graphically the periods and phases of muscle contraction is called a *myograph*, of which we have several forms. When a muscle is coupled to this



apparatus and stimulated, the resulting muscle curve that is traced gives us an accurate knowledge of its contraction. The abscissa gives us the duration of the contraction, and the ordinates give us the degree of contraction at any particular time in its cycle. By a parallel chronographic tracing accurate periods of time can be read off on the abscissa.

**A simple muscular contraction.** When a single induction shock or momentary stimulus is applied to human striated muscle, the myograph records : (1) A so-called *latent period*, which elapses after the muscle is stimulated, before we get a reaction. It lasts usually .01 of a second, often less, and its relation to the negative variation is such as to lead us to believe it is the time taken in the production of this change. (2) A period of *increasing energy* or contraction, in which the ordinates show a slow, then a rapid and then again a slow rise, lasting .03 to .04 of a second. (3) A period of *decreasing energy* or elongation, in which the fall is first slow, rapid and slow, lasting about .04 of a second. The total cycle is thus from .08 to .09 of a second. There is a period of after vibration that varies with the weight and elasticity of the muscle. The *breaking* shock produces in muscle a stronger contraction than a *making* shock. In the long muscles, as the sartorius, the progress of the wave of contraction can be measured, and is found to be 12 or 15 feet per second. Muscle fatigue lowers the curve of contraction and lengthens the latent period. A contraction from a single stimulus shortens the muscle to nearly one-half of its original length.

**A summation of contractions, or tetanus.** Each time a muscle receives a strong induction shock it responds with a full contraction, but this is not the maximum amount the muscle can contract under repeated stimuli.



If a muscle receive a second impulse of proper strength when at the apex of its curve, it will respond with a second contraction, and the sum of the effect produced will equal the height of the two contractions. This may be continued by repeating the stimuli until the muscle reaches its maximum amount of contraction, something like one-fourth of its original length. When these stimuli are repeated at intervals of less than the duration of a single contraction, a summation of contractions occurs and the results accumulate until the muscle remains fixedly contracted during the period of stimulation, and we call this condition *tetanus* from the similarity in result to that induced in the disease of this name. It cannot long be maintained with a weak stimulus, without increasing the strength of the stimulus. The number of stimuli necessary to maintain this state in human muscle is not less than 20 per second. If kept up for some time the muscle does not at once return to its normal length, but remains temporarily partially contracted (cramp).

**Muscle irritability and fatigue.** The activity of muscle tissue depends upon a proper supply of nutrition, and if long cut off from this supply it loses its irritability. We also know that muscles, perfectly supplied with blood, after prolonged activity become fatigued and are incapable of further action. This is the result of the accumulation of the decomposition products, often called "fatigue stuffs" in the tissues, as we would expect from past studies. Time (rest) suffices for the removal of these accumulative products, but it can be hastened by stimulating the action of the skin, etc., or by massage. (Turkish bath.) These products are peculiarly apt to accumulate in muscles that are put to unaccustomed exercise, while habitual exercise of a proper character (training) greatly in-



creases the eliminative power of these organs. That it is the presence of these fatigue stuffs alone that is often the cause of muscular incapacity, is proven by the fact that if a prepared muscle be stimulated until it will no longer respond, and we then wash out its vessels with a simple saline solution, its vigor is renewed.

**Muscle tone.** While the tracing of a tetanized muscle is a straight line, the contraction is produced by a series of variations in tension that cause the muscle to give forth a distinct tone or note. This muscle tone can often be heard, sometimes in the disease called tetanus. It corresponds to a note produced by vibrations of 20 or more to the second.

**Non-striated muscle.** For the histology, nerve supply and peculiar distribution of this tissue you will refer to previous lectures. Its response to stimulation is not rapid like that of its kindred tissue, but is slow and steady, the contraction wave passing from cell to cell. There are two points in the body, however, in which it is possessed of reasonably rapid movement, viz., in the iris and in the intestinal coats. It is slowest in the blood vessels and next perhaps in the uterus and its latent period in the uterus is about one second. Cardiac muscle responds poorly to electrical stimulation but is singularly sensitive to mechanical stimulation, as evidenced in the palpitations produced by the upward pressure of an overdistended stomach, (carminatives). Rigor mortis invades all muscular tissues, even the uterus responding to the extent of a post mortem expulsion of its contents.

**Application of the skeletal muscles.** With few exceptions skeletal muscles are attached at both origin and insertion to bones, which they move as levers. The bones of the body represent all of the three classes of levers. One bone may be made to illustrate all of the



three. The ulna (and radius) represents the first in striking a blow, the second in raising the body on the extended arm, and the third in lifting a weight in the hand, in the semiflexed position.

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## CHAPTER XII.

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### THE NERVOUS SYSTEM.

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The nervous system includes the various mechanisms by which the distant parts of the body are kept in functional relationship with one another. The brain and spinal centres are kept informed of the condition of various parts of the body and its surroundings, and in turn regulate the activities of the various organs. In other words it is the telegraphic system of the organism.

**A sketch of the system and methods of study.** We have seen simple protoplasm (amoeba) receive and transmit impulses, and on a higher scale we saw the same power possessed by muscle fibre, but the transmitter of nervous impulses in the body is a highly differentiated and delicate protoplasmic cell process specialized for this purpose. As in the telegraphic world some of these nerve cell processes are insulated (medullary sheath), and some are not, but all have on their line of conduction a relaying battery or cell body to energize the impulse they have received. When we see that the fibrils that conduct and the cell bodies—that relay and receive are all microscopic in size and complex in arrangement, we will understand the difficulties of their dissection. When the fibres are in small groups or isolated cords the problem is easy, but when the fibres run in large



complex cords (as in the spinal axis) or traverse masses of other nervous tissue, dissection is impossible. The following methods have been used to trace the fibres in such cases. (1) *Turck's method*. Discovering that nerve fibres degenerate when severed from their controlling cells, he studied the degeneration that resulted from the destruction of certain limited areas of the brain, etc., in man and the lower animals. (2) *Gudden's method*. As we saw, Turck destroyed or at least studied the results of the destruction of the central endings of the nerve fibres. The author of this method, on the contrary, applied the principles of degeneration by destruction of the peripheral endings. He removed in very young animals an eye or an extremity, etc., and then noted at a later period the central degenerations that ensued. (3) *Flechsig's method*. At a later date the author of this method observed that in the embryo certain bundles of nerve fibres in the brain and spinal cord become completely developed before others. By means of sections of embryonic brains he was able to confirm the result obtained by Turck's method. (4) Following upon these experiments come those of *Ferrier* (and *Munck*), who, exposing the cortex of the brain, stimulated the centres learned from degenerative methods, and noted the muscular reaction that followed. (5) Finally the study of the comparative anatomy of the nervous system, by *Spitzka* and others, showed that in some animals environment and habits of life had produced degeneration of certain organs, and consequently of their nerve supply, and from this source much was learned. So far from the standpoint of history.

(6) In the early part of this decade *Weigert* devised a process of staining by which nerve fibres, whether degenerated or not, could be the better traced, and *Golgi* soon after began the improved methods of staining



by which the true histological structure of the nervous system was first clearly brought out. The work of these men, with that of Ramon y Cajal and His, has absolutely changed our ideas of nervous structure. First, the old idea of a nerve "fibre" connecting two remotely located nerve "cells" has been shown to be false. The structural frame work of the nervous system, the neuroglia, is now known to contain but one functional unit, the true nerve cell or *neuron*. From this neuron, and usually from opposite poles, grow out processes.

The first type of these, a long slender and but slightly branched cell process, is called the *axon* and as it is often in the major part of its course covered with a medullated sheath, it is recognized as our old friend, the "medullated nerve fibre." The few branches coming off from an axon, called "paraxons," come off at right angles to the main process, and end in fibrillated tufts by simple free terminals. The other type of process, far less highly specialized, seems but a protoplasmic outgrowth of the cell. In most cases, however, it rapidly subdivides and forms an aborescent expansion of terminals called *dendrites*. The cell body from which these nerve processes or "fibres" extend is of various sizes and shapes, but seems always to show a cell wall and an intercellular stroma with which the axonic process seems to be continuous. The cell processes, while always slender, vary greatly in length, some being but the fraction of an inch while others are a yard or more long; for example, the axons and dendrites which form the nerve "fibres" of the nerve trunks of the lower extremity have their neurons in the cord and on its posterior root. The route, therefore, of the nerve impulses from, let us say, the foot to the brain and the brain to the foot, is made up, as



far as conduction is concerned, of a series of nerve cells or neurons with their long conductive nerve processes on axons and their more arborescent terminals, the dendrites. The most singular thing in connection with this chain of conductile units is that *the terminal processes of one neuron never fully touch those of another*. The axons come quite near to the dendrites and it may be that in the active state they extend their terminals and touch, as a part of the act of conduction, but in the cell as seen in the dead body axonic and dendritic terminals are always free. As far as the body of the neuron is itself concerned, the dendrites are functionally afferent (cellulipetal), while the axons are the bearers from the cell of efferent impulses (cellulifugal). In short, in nerve conduction we now have, in the place of the old hypothetical conjoined nerve cells and fibres, a chain of anatomically isolated units. In figurative terms the dendrite of a neuron receives a stimulus which it conducts to the cell body, from this point it is relayed, so to speak, to the axon and proceeds to the axonic terminal. Here, in a manner not yet understood, it is conveyed by means of another neuron, on toward the higher centres and brain. In the cortex of the brain it must, as we can see, reach a final neuron where conduction ceases and perception, or a voluntary or even a reflex efferent return, begins. In corroboration of the last there are monaxonic, di-axonic and polyaxonic neurons both in the cortex and in the cord.

From the above we see that we should, in the strict sense, no longer speak of nerve "cells" and nerve "fibres," and yet, not only is it impossible to overcome the usage of years in a day, but if we use the terms cell and fibre, with a due appreciation of what they are known to be, we cannot improve on them.



**Functional classification of nerves.** Cell processes on "nerve fibres" may, still as previously agreed, be classified according to their function. In modified form, then, as compared with page 34, we may classify them as follows :—(1) *Afferent nerves*, which bear impulses from the periphery to the centres. They are called *sensory* when they convey an impulse which will give rise to a percept regardless of whether this perception come through the nerves of special sense (sight, taste, smell or hearing) or through the nerves of general sensation. The term general sensation includes the sense of touch, of temperature, of muscle sense, etc., or the *exaggeration of these, pain*. Certain afferent impulses which arise from the viscera, etc., may induce reflexes of motion, secretion, or inhibition, without giving rise to a mental perception, and such afferent impulses are called *excito-reflex*. These may, however, bear vague impulses of general sensation, as impressions of hunger, fatigue, etc. (2) *Efferent nerves*, which carry impulses from the centres to the various organs throughout the body. Those which go to the muscles, either striated or non-striated, are called *motor* impulses. Those which call forth the activity of a gland, *secretory* impulses. Those which check or prevent some activity by the impulse which they carry, *inhibitory*. Those which seem to control the nutritive processes or metabolism of the various tissues, *trophic*, etc. (Electric impulses in electrical fishes belong to the efferent class.) *Intercentral nerves* act as bonds of union between the several ganglionic cell masses or centres of the nervous system. The two sides of the brain, medulla, etc., are intimately united by such fibres. They are often called *associating fibres*.

**Nerve stimuli.** Like muscle, nerves may be regarded as having a state of rest and a state of activity,



but the two states are not obvious in the same striking way as in muscle. As in muscle, the state of activity is brought about as the result of stimuli. With but few exceptions, the same stimuli that produce the active state in muscle will produce it in nerves. The various forms of stimulus for nerves are, (1) The normal or physiological stimulus. Of this we know but little as it is not as yet explainable by any physiological law. We only know that so long as a certain force or "spirit" abides in a healthy body that body will obey its behests in opposition to the physical laws of inertia, momentum, gravity, etc. (2) Electrical stimulation. For both experimental and therapeutic purposes this is the most important of them all for the physiologist. As in the case of muscle, any sufficiently rapid variation in the intensity of an electrical current passing through a nerve will bring about the molecular change which we call excitation, and the nerve will initiate an impulse. (3) Chemical stimulation is produced as in muscle, by the application of various drugs, especially those that abstract water. Ammonia will excite a muscle, but has no effect upon a nerve. (4) Mechanical stimulation will give the same result in nerve as in muscle, while (5) Thermic stimulation is far less intense than in muscle. The poison *curari*, or as it is also called *woorari*, will, if injected into an animal in proper dose, paralyze the last neuron, next the muscle, and prevent all muscular action. Its influence on afferent nerves is uncertain.

**Electrical properties of nerves.** In a nerve, as for example a section cut from the sciatic, we find the same natural electric current that we find in muscle similarly excised, and we get much the same negative variation when the nerve is similarly stimulated. We also find that if an excised nerve be tested either at the



two poles or at any two points equidistant from the equator, a constant current flows in it called the *axial current*, in a direction contrary to the normal direction of its impulse. We can therefore see that the so-called negative variation is here a more complex change than in muscle. Using the electric current in experimentation on nerves, we find it best to stimulate by placing the wires from a battery at different points on the nerve. In view of the fact that it is the *variation in the intensity of a current that initiates the impulse* in a nerve, the question arises, at which pole does the impulse start? As the current enters the nerve at the positive pole or anode in a making shock, and leaves it at the negative pole or cathode in a breaking shock, we would expect the impulse to begin at these points respectively. The facts are found to be just the contrary. In a *making shock* the stimulation takes place at the *cathode*, and with a *breaking shock*, at the *anode*. If a strong constant current pass through a section of nerve for some moments, we get on breaking in place of a simple contraction a temporary tetanus (Ritter's tetanus). The impulse is always stronger with a given current the more distant from the muscle the stimulation be applied to the nerve (avalanche theory?). The impulse wave travels in nerve at about 35-40 yards per second, a little more than ten times the speed of the contraction wave in muscle.

**Electrotonus and its results.** When a constant current is passed through a section of nerve the natural currents disappear, and in their place is a current running throughout the length of the nerve, and in the direction of the exciting (polarizing) current. It is most marked near the polarizing current. The passage to this condition, the state of electrotonus, is evidenced by pronounced changes in the irritability and con-



ductivity of certain parts of the nerve. Great *increase of irritability* is seen in the region of the *cathode* (catelectrotonus,) and marked *decrease of irritability* in the region of the *anode* (anelectrotonus). Between the electrodes in the intra-polar region lies a point in which the irritability and conductivity is normal, called the *indifferent point*. With a strong current this point moves toward the cathode, and reduction and exaltation of excitability are respectively intensified. The result is that almost the whole intra-polar segment becomes anelectro-tonic and incapable of conducting an impulse. There is a variation in the results of this polarizing current, dependent upon whether it flows with the course of the nerve's impulse, a "descending" current, or against it, an "ascending" current, and also in the results that follow the opening or closing of the circuit.

**Degeneration of nerves.** Nerve fibres remain in a condition of normal nutrition only so long as they are connected with their "centre" that presides over the nutritive or trophic processes in the nerve. Late studies seem to indicate that the body of the neuron is the centre which presides over the nutrition of its axons and dendrites. The trophic centres, or cell bodies for the *motor* spinal nerves are in the anterior horn of the cord at their origin, while the trophic centres for the *sensory* spinal nerves are in the ganglion on the posterior root. When any part of a *nerve* (spinal) is separated from its trophic centre, in from four to six days it will begin to *degenerate*, and so continue till in two weeks or more the peripheral or cut-off portion is functionless. The fibres of the stump the next cord, or brain, degenerate very slowly, and then only from functional inactivity. This is called *retrograde degeneration*.



The cut or injured fibres of the spinal cord itself always degenerate in the direction of their impulse. Lesions of the sensory columns degenerate upward from the point of section (ascending) and the motor columns downward (descending).

**Reaction of degeneration.** *Muscles* which have been, for some time, cut off from their *spinal* centres of control present a peculiar response to electrical stimulation. The motor nerves which supplied them being "dead," and irresponsible, we would expect no response from the muscle, but we find as follows:—To the *induced* or faradic current, to which a muscle is usually most susceptible, *no response*, or at most a feeble one; while to the *constant* or galvanic current the *contraction*, while not so strong, is more prolonged than usual. We also get C. A. C.=C. K. C. which is against the rule, but the first is the more practical test. When we learn that a muscle paralyzed by injury of the motor cortex or cord above the level of its spinal segment does not present the reaction of degeneration; while injury to its (motor) spinal nerve or the cord at its segment does give this reaction, we can see the practical uses. In short it sometimes enables us to differentiate central and peripheral palsies. The other practical applications of electricity in diagnosis are, in addition to the above, to unmask malingerers, to prove the existence of death, to detect metallic bodies in the tissues, etc.

**Functions of nerve cells or neurons.** The nerve cells or neurons are the real actors in nervous operations, the fibres as we have seen being but their agents. Terminal cells (neurons) of various kinds are placed in all the superficial parts of the body, and receive through their dendrites impulses of the most varied kinds. Some of the more highly specialized types



(special sense terminals) receive only luminous, sonorous, odorous or gustatory impulses. Others, by far the greater number, (touch and temperature corpuscles) are generally distributed over the entire body, where they will be brought into contact with the mechanical and thermal conditions surrounding the body, and make known to us our environment. Still other cells are more deeply placed in the tissues to act as local distributing agents of impulses, as the visceral ganglia, etc. Still others, deep in the tissues, report upon the conditions of functional activity, as pressure and muscle-sense, etc. In addition to and above all these are the aggregated masses of central neurons which we term *centres*. These have not only the power of receiving through their dependent neurons impulses to be co-ordinated and recorded, but some have a still higher power, that of *initiating* impulses which appear as movements, etc., in the organism. Taking no note of the psychological and spiritual questions here involved, we may say that the nerve centres possess the powers of reflexion, augmentation, inhibition, co-ordination and automatism, while in them we also find the powers of higher mental activity, including perception, volition, memory and thought.



## CHAPTER XIII.

## THE SPINAL CORD AND ITS CENTRES.

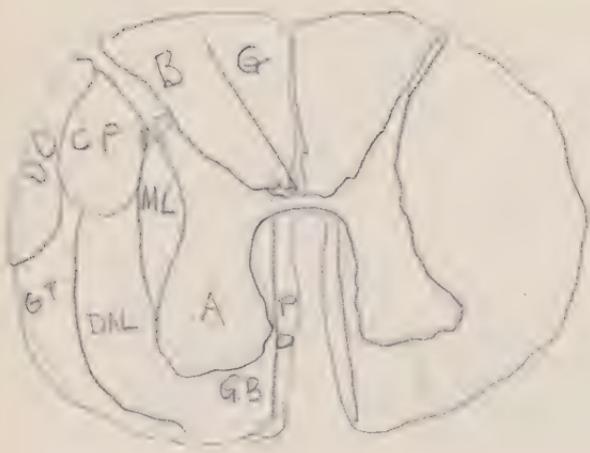
The **spinal cord** includes not only the anatomical cord, but the medulla, with its nuclei and cranial branches, the pons varolii and its peduncles, and the diverging crura cerebri above. In the study of these parts we will pass from the simple to the complex, and hence we will take up the cord from below up, in order, leaving the complex nerves of the medulla and their nuclei for further study.

**The spinal nerves.** The thirty-one pairs of nerves which leave the spinal canal by the intervertebral openings are called spinal nerves to distinguish them from the cranial nerves above. They are all attached to the spinal cord by two roots, an *anterior* or *motor* root, and a *posterior* or *sensory* root which has on it a rounded ganglionic enlargement, the trophic ganglion. These roots unite in the intervertebral canal, and from this point the nerve is a *mixed nerve*, that is capable of carrying both sensory and motor impulses. In short a spinal nerve trunk consists of the axons (motor) and dendrites (sensory) of neurons which are found in the gray matter of the cord and in the ganglion on its posterior root. Studied as a whole, a typical segmental spinal nerve, formed as above, consists of three branches on each side. These are (1) The posterior primary division, small in size and supplying the muscles of the back and dorsal integument with motion, sensation, etc. (2) The anterior primary division (somatic), the largest and most important, supplying the body wall and the



limbs, where they exist, with motion, sensation, etc. (3) The visceral or splanchnic division (ramus *communicans*) unites the spinal axis with the sympathetic gangliated cord, and supplies the viscera, blood vessels, etc., with vaso-motor, excito-reflex, sensory and motor filaments.

**The spinal cord, its structure, etc.** The cerebro-spinal axis consists of neurons and their processes held together by neuroglia. Where the neuron body is found the color is dark or gray, where only axons and dendrites are grouped it is white. Hence the cord will show us two distinct kinds of substance, the white matter and the gray. In the brain the gray matter is chiefly on the surface (cortex), while a smaller portion is in the central part, with the white fibres between. In the cord the gray matter is all in the centre, and the white fibres surround it. This gray matter is arranged roughly in the shape of a letter **H**. The parts corresponding to the two verticals are called respectively the right and left *cornua*. The horizontal portion is the *gray commissure*, anterior or posterior as it lies before or behind the central canal. The periphery of the cord is marked by the following points. In the central front part is the *anterior median fissure*, outward from this on either side the funiculi of the anterior roots, while the *post. median fissure* (?) is in the centre behind, and lying externally to this the posterior funiculi. The white tracts (communicating fibres) within the limits marked above are, (1) The *direct pyramidal tract* (Turck's) lying on either side of and contiguous to the anterior median fissure (motor). (2) The *postero median tract* (Golls) lying on either side of and diverging from the posterior median fissure, (sensory). (3) The *postero external tract* (Burdachs) lying external to the above and extending outward on either side to



the posterior roots (sensory). (4) The *direct cerebellar tract*, a thin superficial plane of fibres extending forward on either side almost to the funiculi of the anterior roots (excito-reflex). (5) The *crossed or lateral pyramidal tract*, a large column that came originally from the opposite side, and here lies between the above and the gray cornua of either side (motor). (6) The *anterior root zone* is the region lying around the funiculi of anterior roots and extending from the direct pyramidal tract on either side, outward and backward to the direct cerebellar tracts before mentioned (mixed impulses). The gray matter is subdivided into the following parts—*anterior (motor) and posterior (sensory) gray column*, applied to the anterior and posterior extremities of the gray cornua respectively, and the vesicular column (Clarke's) found in certain parts of the cord, in the angle between the post-gray column and the gray commissure. The white tracts viewed collectively give the *anterior and posterior white columns*, each pair united by the *anterior and posterior white commissure*, and on the lateral aspect of the cord the *lateral white columns*.

**The medulla oblongata.** This is the expanded portion of the cord at the base of the brain. It consists of the representative parts of the cord above given, with some additional gray matter. To picture the true changes taking place here in the parts of the cord, imagine the posterior median fissure spread wide open, down to the central canal, as by the thumb nails. The open space disclosed is the *floor of the fourth ventricle*. Observe that this would bring the anterior gray columns nearer the median line, and the posterior gray columns nearer to the lateral parts of the floor. The important changes in the relationship of the white columns in the medulla are the following: The white



lateral column almost disappears in the medulla, as its direct cerebellar tract becomes the restiform body, and forms the inferior peduncle of the cerebellum, while the large crossed pyramidal tract goes forward and across to the other side to enjoin the direct pyramidal tract on its inner side. The fibres of the posterior median tract are continued into the medulla as the *fasciculus gracilis*, which here expands by reason of the formation of a gray nucleus, the *gracile nucleus* or clava, within its walls. The fibres of the postero-lateral tract, which seem intimately related to those of the above tract, continue upward to form the *fasciculus cuneatus* of the medulla, and here also expand from the formation of a gray nucleus, the *cuneate nucleus*. Some of the fibres of these two columns do not terminate in their respective nuclei, but pass on to join that intermingling of transverse and longitudinal fibres with gray matter, which gives us the so-called *formatio reticularis* in the body of the medulla.

The superadded gray matter of the medulla is found chiefly in the *olivary body*, with its nucleus the *corpus dentatum*, and the other smaller masses are the *gracile nucleus* of the *fasciculus cuneatus*. The pre-existing gray matter of the cord is spread out on the floor of the fourth ventricle, its lower and outer portions entering into the formations of the *formatio reticularis* as described, its chief central portion forming the centres of the medulla which will be given later.

**The pons varolii.** The white fibres that we have followed from the cord through the medulla here have a very simple arrangement. The conjoined pyramidal tracts, now in a more or less rounded trunk, lie deep in the lower aspect (anterior) of the pons, having below it the superficial and above it the deep transverse



bonds that form the *middle peduncle* of the cerebellum. Just under the prolongation of the floor of the fourth ventricle, on the upper (posterior) side of the pons, lies the continuation of the *formatio reticularis* which we saw carried most of the fibres of the posterior (sensory) columns of the cord below. Just outside of this is the *fillet tract*, which connects the spinal nuclei of the medulla with their centres in the cortex. Remember that about the middle of the pons the 7th nerve fibres decussate. (Gubler's line.)

**The crura cerebri.** Just below the anterior (upper) border of the pons the fibres that we have been following are collected on either side into two trunks called the *crura cerebri*, and each diverges to its respective lobe of the cerebrum. The pyramidal tracts lie on the inferior face of their respective crura, called the *crusta*, about the middle line. Above this tract is quite a large mass of gray matter, the *substantia niger*, while above this, rather on the lateral aspect of the crura, is the *tegmentum*, which carries the fibres (sensory) from the *formatio reticularis* of the pons and medulla, and in which we also find the fillet tract above-mentioned. Above the inner border of the *substantia niger* is the *red nucleus of Stilling*. On the upper surface of the posterior part of the crura, before they diverge, are the *corpora quadrigemina* (which will be studied later) and under them, in the median line, lies the prolongation of the central canal of the cord, the aqueduct of Sylvius (iter a tertio, etc.). This canal, as in the cord, is surrounded with gray matter which is most abundant below, the part corresponding to the prolongation of the floor of the fourth ventricle. Above the crura the tracts we have been considering pass chiefly into the *internal capsule*, a broad band of white fibres lying between the basal ganglia, and to be



studied later. From thence our tracts pass through the *corona radiata* to the *cortical centres* of the brain.

**Functions of the spinal tracts.** While in the previous histological study of the cord, etc., we did not consider with care their course, we will now take the fibres in the direction of their impulses. The voluntary *motor nerves* of spinal distribution leave the cortical motor centres, pass through the internal capsule behind the knee, through the pyramidal tract of the crista in the crura, between the deep and superficial transverse fibres in the pons until they reach the medulla. In the upper part of the medulla the motor fibres decussate. The bulk of them cross over to the other side, and go down in the crossed pyramidal tract, where they pass into the anterior gray column (trophic centre) when they reach their level of distribution, and from thence out through the anterior roots to their distribution. The remaining motor fibres, few in number, continue on down on the same side, forming the direct pyramidal tract of the cord. When they reach their level of distribution they pass across through the anterior white commissure to the ant. gray column of the opposite side, where they join the fibres from the crossed pyramidal tract and go out through the ant. roots with them. As regards the involuntary motor impulses, as the *vaso-motor*, etc., we have reason to believe that they descend from the vaso-motor centre of the medulla, through the post. part of the anterior root zone to their level of distribution, and then they go out through the anterior roots to join the *rami-communicantes*. The *sensory* and other afferent routes in the cord are but imperfectly understood. We can only give reasonable conjecture as regards many of them. We know that coming from their peripheral terminals they enter the cord at



its posterior or gangliated root. This root enters the cord seemingly as a single trunk, but it is in reality three, an internal, middle and external division. The internal fasciculus, believed to carry the impressions from the tendons (muscle sense) and those of touch and locality, as it enters sweeps around through the postero-external tract, and some fibres curve sharply upward before joining the gray matter. The external fasciculus, carrying impressions for the cutaneous reflexes and temperature, also curves upward to join the posterior gray columns. The middle fasciculus, as well as the most internal fibres of the other fasciculi, run straight in to the gray horn and seem to carry impressions of pain. Within the cord the routes are still more varied. The fibres carrying the impressions of pain possibly travel through the gray matter, although observations made by Gowers and others point to the mixed tracts, behind the anterior root zone, as the place of pain conduction. Those of touch, temperature, and muscle sense travel in the posterior column, the impulses from the lower extremities chiefly in the postero-median tract, and those for the trunk and upper extremity chiefly in the postero-external. (locomotor ataxia). All of the fibres of the posterior root are processes of the small neuron cells of the post. root ganglion, which act as relays to the impulse, before a second distribution on its route. One set of these fibres are processes of the cells of Clarke's column, and from this point they run horizontally outward through the crossed pyramidal tract to join and ascend in the direct cerebellar tract. This vesicular column of Clarke is only found in certain parts of the cord, being most pronounced in the dorsal region, and it would seem to transfer to the direct cerebellar tract those afferent (excito-motor) impulses which come from



the viscera. The fibres for the direct cerebellar tract do not decussate, but ascend on the same side in which they entered the cord. All the other fibres carrying impulses of touch, temperature, pain, and perhaps muscle sense, soon decussate or cross over to the posterior median, the postero-lateral or gray tracts of the opposite side (sensory decussation.) None of these decussate on entering, but all of them cross shortly after, touch first, pain, etc., next, and temperature last. This decussation of all nerves carrying cutaneous and other reflexes applies also to the cranial nerves. (Experimental section of the cord.) Above, in the medulla, the impulses coming up through the postero-median column break joint in the gracile nucleus, the postero external in the cuneate nucleus, etc. Above this some pass to the cerebellum through its posterior peduncle, and some through the fibres of the formatio reticularis to the tegmentum and thence to the sensory basal ganglia (optic-thalamus) and cortex.

**Reflexes of the cord.** Having considered the tracts and conducting powers of the cord, we come now to study its powers of reflexion. By a reflex movement or action is meant one caused by the stimulation of an *afferent* nerve. The impulse is carried centripetally in the afferent nerve, and then by central transfer to an efferent nerve is carried centrifugally to the muscle, etc., of action. A simple reflex is one in which a single muscle, or at least a single group of muscles, is called into play by the stimulation, as, for example, reflex closure of the lid from conjunctival stimulation.

A radiating or incoordinate reflex is one in which, either by reason of the intensity of the stimulus or by reason of the excitability of the centre, other groups of muscles or even of all the muscles of the body (spasm) are thrown into action. Various poisons or drugs, as



strychnin, etc., will produce this condition of exalted excitability. Complicated coordinate reflexes may be excited where the movements are "purposive" in character, but they are the result usually of experience (habit), for example, the guarding of the head from a quick blow, the peculiar balancing and other complicated feats of a decapitated frog, etc. The inhibition of reflexes may be voluntary, as by the will, for example, keeping the eye open while the conjunctiva is touched, etc. Inhibition may also be produced by the strong stimulation of a sensory nerve, as for example, preventing sneezing by pinching the lip, etc. Certain drugs, as chloroform, chloral, morphin, etc., lower reflex excitability by depressing the action of the centres. The reflexes are of much service in diagnosis. They are divided into the *superficial* and the *deep* or tendon reflexes. The superficial reflexes are the plantar, cremasteric, gluteal, abdominal, etc. The deep reflexes are the patella reflex, ankle clonus, etc. They test the condition of the cord at the "point of reflection."

**The centres of the spinal cord.** Within the cord lie several centres, some of them seemingly independent, while others are more or less under the control of the higher centres. They are (1) the cilio-spinal centre, in the upper dorsal cord; (2) the ano-spinal centre; (3) the vesico-spinal centre; (4) the copulation centre, and (5) the parturition centre. The last four all lie in the lumbar cord. The spinal vaso-motor and sweat centres are subservient to the medulla.



## CHAPTER XIV.

## THE CRANIAL NERVES AND THEIR FUNCTIONS ;

In addition to the thirty-one pairs of spinal nerves taking origin from the cord, we have twelve or more pairs that arise from the medulla and brain, and are hence called the *cranial nerves*. Two of these, the most highly specialized, run more or less directly from the cortex of the brain, but all the others arise from special nuclei in that mass of gray matter forming the floor of the fourth ventricle, and its prolongation, the aqueduct of Sylvius. As before shown, the most central parts of this gray matter are formed from the anterior or motor cornua, while the lateral parts are formed from the posterior or sensory cornua, and as a result the nerves arising from nuclei near the median line are usually motor, and those from lateral nuclei more or less sensory. Always remember that both spinal and cranial nerves are constructed on the same general plan. The old classification of Willis, while fixed in anatomical nomenclature, is absurd for physiological purposes, and we will use the classification of Sömmering. The histological and physiological bearings of the nerves only will be given here ; for further details of anatomy, etc., see "Scheme of Nerves," at the end of the book.

**The floor of the fourth ventricle.** As all the cranial nerves except the first two take their origin from nuclei in this floor and its upward prolongation, we will consider this area in minute detail. The diverging columns of the fasciculus gracilis bound, its posterior



triangle, the *calamus scriptorius*. The inner border of the superior peduncles of the cerebellum (*valve of Vicussens*) limit its superficial area above, while the lateral limits extend to the middle cerebellar peduncle. In the median line is a fissure, which divides the floor into equal parts, and ends below in the central canal of the cord, while above it extends onward as the aqueduct of Sylvius. Under the surface so bounded are masses of gray matter in varying quantities, and the same nerve tissue is prolonged forward as a tube around the aqueduct of Sylvius. The macroscopic appearances on either half of this floor, from before backwards, are as follows: The *locus coeruleus*, a spot of bluish tint on the anterior part of the floor partly under the edge of the valve. Just below this is the *eminentia teres*, a projection caused by the nucleus of the 6th nerve, while extending backward and forward from the inner side of this eminence is a ridge, the *fasciculus teretes*, caused by the cerebral fibres of the posterior column passing upward to the tegmentum. In the lower part of the *calamus scriptorius*, and next the median line, is an eminence marking the nucleus of the 12th nerve, and just above this is a triangular area of ashy color, the *ala cinerea*. On section and histological study we find the various nuclei of the floor to be located as follows: On the floor of the aqueduct of Sylvius, just under the anterior corpora quadrigemina, and above the red nucleus, is the nucleus of the 3d nerve. Just behind it, and conjoined with it, under the posterior corpora quadrigemina, is the nucleus of the 4th, both being close to the median line. Just under the *eminentia teres* is the nucleus of the 6th. Slightly behind and to the outer side of the above nucleus, and much deeper in the floor, is the nucleus of the 7th nerve. The nucleus of the 5th is a very complex one. There



is a small (motor) nucleus lying externally and anteriorly to the eminentia teres, but external to this and extending from about the level of this nucleus down in the posterior cornua of the cord to the level of the second cervical vertebra is the long (sensory) nucleus. A part is cut off from the rest. Both sensory and motor nuclei are deep in the floor, the latter being the deeper. The nucleus of the 8th nerve is likewise a double one, or more truly there are two nuclei, each of which is double. There is an internal pair located just behind the eminentia teres, and an external pair at the very lateral limit of the floor and at about the same level as the other. The nucleus of the 9th nerve is partly in front of and partly under the ala cinerea (the so-called 13th nerve of Wrisberg has a common nucleus with it). Part of its nucleus is quite near the median line and part at some distance. The 10th nerve nucleus lies under the ala cinerea abutting the nucleus just given, and it is the more superficial of the two. The nucleus of the 11th nerve is below the preceding, and but to a slight extent under the floor, being mainly a spinal nerve. Its nucleus at the point mentioned is separate and distinct from the spinal nucleus, which is in the outer side of the anterior cornua of the cord, extending as low down as the fifth cervical vertebra. The nucleus of the 12th nerve lies internal to the medullary nuclei of the three preceding, and is very superficial.

**First cranial or olfactory nerve.** The cortical centre for this primitive sense is probably the gray matter covering the anterior superior aspect of the temporo-sphenoidal lobe, and called the *uncinate gyrus*. From this point a long band of fibres runs backward and upward, decussates (olfactory chiasm), passes forward to groove the head of the caudate nucleus, and emerging from the fissure of Sylvius is joined by an internal and



external root, forming the triangular *olfactory tract* which joins the *olfactory bulb*. These two short roots are from the side of the brain on which they join the tract, but their origin is uncertain. From the inferior surface of the bulb, which lies on the cribriform plate, run from 15 to 20 filaments, downward through the foramina. The filaments at first run under the mucous membrane, grooving both the vertical plate and lateral mass, but ultimately pierce the membrane and appear superficially, over the *regio olfactoria*. This nerve is excited only by gaseous odorous bodies, but any form of stimulation of the trunk gives a sensation of smell.

**Second cranial or optic nerve.** The cortical visual centre is found in the *cuneus* of the occipital lobe. From this centre a broad band of fibres (optic radiation of Gratiolet) converge to join the pulvinar and the external geniculate body. Receiving fibres from these bodies, and through them from the cerebellum, the *optic tract* is formed, and sweeping around the crura the two tracts meet in the *optic chiasm*. In the chiasm there is a decussation, in which about half of the fibres of each tract cross, the right tract sending fibres to the right half of the left eye, and the left tract fibres to the left half of the right eye. The outer half of each retina is supplied by the fibres of the tract on its own side. After leaving the chiasm each *nerve* proceeds through the optic foramen to its respective eye and ends in the retina. The optic nerve is the special sense nerve of sight, and can be excited only by the influence of the vibrations of the luminous ether on the rods and cones of the retina. Other forms of stimulus produce only the sensation of light. Hemianopia is usually caused by injury to one of the tracts (homonymous) but injury of the anterior part of the chiasm



will produce double nasal hemianopia, and the outer half of each tract double temporal. Communicating fibres pass from the ant. corpora quadrigemina to the nucleus of the oculomotorius. The converging fibres of the radiation pass through the lower posterior part of the internal capsule.

**The third cranial nerve or motor oculi.** From its nucleus, this nerve without *apparent* decussation sinks down through the crura to the post. perforated spot. Its nucleus is united by fibres with the corpora quadrigemina above and with the nuclei of the 4th and 6th nerves on the floor. The nerve in the orbit is connected with the ophthalmic (ciliary) ganglion by a short root. It carries (1) motor fibres for all the external muscles of the eyeball, except the external rectus and superior oblique, and also fibres for the levator palpebrae; (2) motor fibres for the sphincter pupillae; and (3) motor fibres for the ciliary muscle. Impulses for the two latter pass through the ganglion (atropia).

**The fourth cranial nerve or trochlearis.** From its nucleus this nerve passes backward and upward, decussates, pierces the valve of Vieussens, and turning outward runs around the crura cerebri to their outer side and makes its way to the orbit. Its nucleus receives fibres from the nuclei of the 3d and 6th. It supplies motor fibres to the superior oblique or trochlearis muscle.

**The fifth cranial nerve or trigeminus.** In the cranial nerves so far considered the departure from the spinal nerve type has been pronounced, but here we meet a nerve bearing strong analogy to the spinal nerves considered. From the long sensory nucleus and its anterior isolated extremity a large band of fibres starts. This is joined by a band of fibres from



the motor nucleus, and together they pass outward and downward to emerge about the middle of the pons on either side, the motor fasciculus being, as it started, on the inner side. It should be noted here that these roots have no direct decussation, but that their nuclei, especially the sensory nuclei, have intimate bonds of union, not only with their fellows of the opposite side, but with all the other nuclei on the floor. In addition to this, fibres of communication unite their nuclei with the cerebellum and also the corpora quadrigemina. Hence the vast number of reflex relations of the 5th nerve. From its apparent origin from the pons it runs forward, where its sensory root develops a large ganglion, the *Gasserian ganglion* (trophic). From this point the sensory trunk divides into *three* branches, as follows :

(1) *The Ophthalmic Division.* It gives first a recurrent branch to the tentorium cerebelli, etc., then the *lachrymal*, which gives sensation to the conjunctiva, upper lid and contiguous parts, and secretory fibres to the lachrymal gland. The *frontal* of this division gives off branches of sensation to the upper lid, brow and forehead as far as the vertex. The branches of the *nasо-ciliary* after devious routes supply sensation to the lachrymal canals and sacs, the bridge, tip and alae of the nose and the mucous membrane of the nasal fossa that covers the cartilages, septum and turbinated bones (sneezing). The *nasо-ciliary* also gives the long root for the *ciliary* or *ophthalmic ganglion*, and the long *ciliary* nerves of the eye, carrying sensory and trophic impulses. [*The ophthalmic or ciliary ganglion* will be considered with this (ophthalmic) division of the 5th. It receives, by its short, root motor fibres from the 3rd, by its long root, as stated above, sensory and trophic fibres from the 5th, and by means of the



sympathetic root, from the carotid plexus, motor and vaso-motor fibres. It *gives*, by the ciliary nerves, sensation to the cornea, iris, choroid and sclerotic, vaso-motor fibres for the iris, choroid, etc., motor fibres to the sphincter pupillae (dilator pupillae) and tensor choroidae muscles and trophic impulses for the entire eye.]

(2) *The superior maxillary division.* This division also has a *recurrent* branch, which supplies the dura mater in the region of distribution of the middle meningeal artery. The *orbital* branch supplies sensation to the check and temple. The *dentals* supply sensation to the upper teeth and the cavities of the jaw, by means of their various branches. The *infra-orbital* branch gives sensation to the skin of the face, from the lower lid to the angle of the mouth inclusive. The *spheno-palatine* branches go to the ganglion of the same name. [The *spheno-palatine ganglion*, (Meckel's) will be considered with this (Sup. Max. Division) branch of the fifth nerve. It *receives* motor fibres from the 7th, via the great superficial petrosal, (vidian), sensory and perhaps secretory fibres from the sympathetic (vidian). It *gives* sensation to the post. portion of the mucous membrane of the nasal cavity, and the hard and soft palate, etc., through its nasal, naso-palatine and post. palatine branches. Motor fibres are also supplied to the azygos uvulae and levator palati through the post. palatine nerves. Secretory impulses to the mucous glands of this area are also sent out.]

(3) *The Inferior maxillary division.* While the branches of the fifth originating from the Gasserian ganglion are all sensory, the motor root follows this division, hence it is really a mixed trunk. The *sensory* branches are a *recurrent*, as in the other branches, the *buccinator*, supplying the mucous membrane of the



cheek and angle of the mouth, the *lingual*, supplying sensation and tactile acuity to the tip and ant. half of the tongue (taste?), the *inferior dental* which supplies sensation to the teeth and the chin, and the *auriculotemporal*, which gives sensation to the tympanic membrane, ant. wall of the canal, ant. part of the ear and maxillary articulation. The motor branches are those to the *muscles of mastication*, the temporal, masseter and two pterygoids; and those which supply the *mylohyoid* and anterior belly of the digastric. [*The otic ganglion*, as well as the other given below, will be here considered. The otic receives motor fibres from the motor branch of the 5th, a secretory branch from the glosso-pharyngeal through the tympanic plexus, vaso-motor fibres from the meningeal plexus of the sympathetic, and a branch of communication from the chorda tympani. It gives motor twigs for the tensor tympani and tensor palati muscles, and secretory fibres for the parotid gland as described. [*The submaxillary ganglion*. This ganglion receives secretory and vaso-inhibitory fibres from the chorda tympani, secretory and vaso-constrictor fibres from the sympathetic, and sensory fibres from the lingual of the 5th. It gives secretory fibres to the sub-maxillary and sub-lingual salivary glands, as well as sensation to the same parts.] The fifth nerve presides over all the trophic processes in the region it supplies (hemiatrophy).

**The sixth cranial nerve or abducent.** From its nucleus on the floor of the fourth ventricle, a fine band of fibres drops down through the substance of the medulla to appear just below the pons and internal to the olivary body. Its nucleus is connected with the nucleus of the third nerve of the opposite side. The function of this nerve is to supply motion to the external rectus of the eye. Its long route and small size makes it



quite subject to injury. Its nucleus seems to be the centre for the coordinate control of eye movements.

**The seventh cranial nerve or facial.** The nucleus of this nerve lies deep in the medullary floor, but the nerve trunk runs from this origin upward to turn down again under the eminentia teres and go out at the lower border of the pons. Passing out through the meatus auditorius internus and aqueductus fallopii, in company with the roots of the 8th and the 13th, the first branch to be given off is the *great superficial petrosal*. This runs from that expansion of the 7th nerve, (called the "geniculate ganglion," but which is not in reality a ganglion) out through the hiatus fallopii, where joined by twigs from the carotid plexus and the 9th, it passes through the foramen lacerum and vidian canal to give motor impulses to Meckel's ganglion, as we previously learned. The next is the branch (small superficial petrosal) from the geniculate swelling to the second *tympanic* twig of the glosso-pharyngeal, as it goes to join the otic ganglion. Then we have the motor branch to the *stapedius* muscle, and after this the *chorda tympani* or 13th, which has thus far followed the 7th, and now leaves it like a branch. After leaving the stylo-mastoid foramen we have a communicating branch to the petrous ganglion of the 9th, and the *peripheral* branches which supply motion to all the muscles of expression, the buccinator, platysma, occipitalis, stylo-hyoid and post. belly of the diagastric as well as the external ear muscles. The facial nucleus is but a subservient centre to the cortical face centre. The cortical area of control for facial movements lies in the lower end of the ascending frontal convolution. From this point fibres pass through the corona radiata to the knee of the internal capsule and down through the crura cerebri to



the pons, where on a level with a line (Gubler's) joining the roots of the fifth nerve, they decussate and join the nuclei of the opposite side. (Crossed paralysis versus normal hemiplegia.) Central and peripheral lesions of the facial are both quite common.

**The eighth cranial nerve or auditory.** As we saw, this nerve arises from two separate pairs of nuclei, therefore we are not surprised to find that it is a nerve of double function, or, more truly, two distinct nerves conjoined, as we saw with the 7th and 13th. One is the nerve of hearing, the stimulation of whose peripheral terminals gives rise to the sensation of sound, the other is the nerve of equilibration, being connected with the semi-circular canals. The *cochlear branch* (auditory). This arises from the two posterior nuclei by a median and lateral root which unite to form the nerve, which accompanies the other branch out through the int. auditory meatus and ends in the terminals in the organ of Corti. The *vestibular branch* (equilibrium). This, like the other, arises by a median and a lateral root, from the anterior pair of the nuclei of the 8th. These roots uniting form the vestibular nerve, which passes with the cochlear nerve outward and ends in the special terminals of the membranous sacs and canals of the vestibule. The nuclei of this branch are in intimate relationship with the cerebellum, while the nuclei of the auditory branch are united with the cortex of the lateral aspect of the temporo-sphenoidal lobe of the opposite side of the cerebrum. This union with the cortex is accomplished as follows: When the fibres from the cochlea reach their nuclei, they are transferred across to the opposite side, up to the post. corpora quadrigemina and internal geniculate body, thence through the most posterior part of (the lower levels of) the internal capsule to the first and second gyri of the temporo-sphenoidal lobe.



**The ninth cranial nerve or glosso-pharyngeal.** This nerve arises from its nucleus, the anterior part of which is likewise the nucleus of the 13th nerve or chorda tympani. Emerging below, internal to the olfactory body, it goes out through the jugular foramen, and at this point its root presents a ganglion, sometimes double, the *petrous ganglion*. At this ganglionic enlargement it receives fibres from the 7th, 10th, and from the sympathetic. It here gives off its tympanic branch (Jacobson's nerve). This nerve pierces the base of the temporal bone, enters the tympanic cavity and divides to form the *tympanic plexus*, which supplies the inner wall of the cavity and sends out a branch to join the great superficial, and one to form the small superficial petrosal, and go to the otic ganglia (parotid secretion) and also one to join the carotid plexus of the sympathetic. The 9th then sends fibres to the posterior one-third of the tongue, and to the arches of the soft palate. These fibres end, some in the taste-buds of the circumvallate papillae and some on the general surface, and they supply this area with the *special sense of taste* and with *general sensation*. It is also the *inhibitory nerve* of respiration during the act of deglutition, and if over stimulated may reflexly excite vomiting. This nerve also supplies *motor* fibres to the stylo-pharyngeus and the middle constrictor of the pharynx, etc. At the same time the glosso-pharyngeal is not truly a motor nerve, being purely sensory at its nucleus, and the motor fibres with which it is later endowed come from the 7th. The glosso-pharyngeal nucleus is believed to be joined with the cortical area presiding over the sense of taste. This centre is believed to be in the inner side of the uncinate gyrus and from this point fibres run down through the tegmentum, pons, etc., to join the glosso-pharyngeal nucleus of the opposite side.



**The tenth carnial nerve or vagus.** The nucleus of this nerve, lying under the ala cinerea, is in part a representative of the cells of the vesicular column of Clark, but other fibres especially those concerned in respiration, take their origin from the gray matter lower down in the cord. From this nucleus, and contiguous parts of the cord, the fibres come out external to the olfactory body, and form the root of the nerve, which passes downward through the jugular foramen. In this foramen it expands into a ganglion, the jugular, which is continued onward to its exit, seemingly making two ganglia. The nerve in the region of this ganglion gives or receives the following communicating branches. A branch from the petrous ganglion of the 9th, the entire inner half of the 11th, and a branch from the sympathetic. The first branch given off is the *recurrent*, which supplies sensation to the posterior part of the dura matter of the brain (cerebral vomiting). The *auricular* branch of the 10th (Arnold's nerve) is joined by a small twig from the 9th, and conjoined they make their way to the external auditory canal, where they supply its floor, post. wall and post. part of the outer ear with sensation. (ear cough.) The *pharyngeal* plexus consists of two or more branches from the vagus, joined by branches from the 9th and sympathetic. The function of this plexus is to supply motion to the three pharyngeal constrictors and sensation to the mucous membrane of the pharynx from the soft palate downwards. The laryngeal branches are two. The *superior laryngeal* goes direct to the larynx, and it divides into an external and internal branch, the former supplying motion to the cricothyroid muscle, while the internal branch supplies sensation to the rima glottidis and the mucous membrane of the larynx and base of the tongue. The



stimulation of this nerve produces reflexly a cough, and an arrest of respiration. There also joins this nerve trunk a branch coming from the heart (sup. cardiac), which carries afferent fibres, for the cardio-motor centre (Cyon's nerve). The *inferior laryngeal* supplies motor fibres to the oesophagus and lower end of the pharynx and to all the muscles of the larynx except the crico-thyroid. (aphonia.) The *cardiac* branches are two, the inferior or thoracic cardiac and the superior or cervical cardiac. The extreme irregularity of anatomical arrangement in these nerves makes their physiological description imperfect and unsatisfactory. However, the inhibitory fibres of the heart come from the trunk of the vagus (low down) while the impulses indicating too great (depressor) or too little (pressor) intra-cardiac pressure pass up, in the superior laryngeal and trunk of the vagus. The *pulmonary* branches of the vagus have the following functions: To supply motor impulses to the non-striated fibres of the whole tracheal and bronchial system. (asthma.) To supply sensory cough exciting (excito-reflex) fibres to the bronchial system and lungs, and to supply sensory fibres whose reflex stimulation shall alternately excite inspiration and expiration, etc. The *oesophageal* plexus is made up of branches from the vagus, at various levels, and supplies motor fibres to the non-striated muscular coat of the oesophagus for its entire length, and sensation (excito-reflex) to the upper part. The *gastric* plexus consists of the right and left branches of the vagus, united with the sympathetics. To the stomach, intestines, etc., the vagus gives motor and vaso-motor fibres and also secretory fibres. The exact influence of the vagus on the other abdominal organs is very largely a matter of conjecture, and will not be given here. It



would seem that the motor fibres of the vagus do not originate from its nucleus, but are derived from the branch it receives from the 11th.

**The eleventh cranial nerve or accessorius.** This nerve arises by two distinct roots from its two nuclei. The root from the medullary nucleus joins the root from the spinal nucleus, but does not unite with it. Together they pass through the jugular foramen, where they divide, the trunk from the medullary nucleus turns inward to join the 10th nerve at its ganglion, while the spinal branch turns outward to furnish the trapezius and sterno-mastoid muscles with motion, just as the internal branch endowed the vagus. (torticollis.)

**The twelfth cranial nerve or hypoglossal.** From the nucleus of the same name this nerve arises and is distributed to the muscles of the tongue, including the genio-hyoid and thyro-hyoid. It endows these with motion only. There is a centre of control for the tongue in the cortex, just below the centre for the face, in the extreme lower end of the ascending frontal (ant. central,) convolution. From this point the hypo-glossal tract runs through the knee of the internal capsule, with the face tract, and down through the pons to decussate at the level of the nuclei above given. Remember that while the hypo-glossal tract supplies the nucleus from the cortex, it is entirely distinct from the speech tract which we will consider later.

**The chorda tympani or thirteenth cranial nerve.** (Wrisberg.) This nerve is usually considered a branch of the 7th, but is distinctly a different nerve. It arises from the anterior part of the nucleus of the 9th nerve. From this point, between the 7th and 8th nerve trunks, as the *pars media* of Wrisberg, it enters the internal auditory canal. It follows the 7th through



the aqueductus fallopii, and about a quarter of an inch before the 7th reaches the stylo-mastoid foramen, it leaves this trunk and runs forward through the tympanic cavity to emerge from the glasserian fissure and join the lingual at an acute angle and follow it on to the sub-maxillary ganglion. Here a few of its fibres join the ganglion, while most of them continue onward, to supply the tips and anterior two-third of the tongue with the special sense of taste. It is also probably united, as is its fellow the 9th, with the cortex of the internal border of the uncinate gyrus of the temporo-sphenoidal lobe of the opposite side.

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## CHAPTER XV.

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### THE BRAIN AND ITS FUNCTIONS.

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**The cerebrum.** The *cerebrum* consists of neuroglia supporting numberless neurons with their axons and dendrites. As a rule the neurons of the brain have relatively short processes as compared with those of the cord. The neuron bodies en masse give the "gray matter" while the grouping of the axons and dendrites into tracts or bundles gives the white matter. The gray matter is arranged in a different manner in the brain from that which we saw in the cord. There the gray matter was only in the interior, but here we have it both inside and out, with the white matter or fibres chiefly between. The superficial gray matter is called *cortical matter*, and follows the sulci and gyri in their folds over the entire surface, without much variation in thickness. The internal gray matter is



collected into masses of various forms and sizes, to which we apply the names *basal ganglia* or *nuclei*. Under this head are included the corpus striatum, with its two nuclei, the optic thalamus, corpora quadrigemina, etc. The functions of these basal ganglia are variable, some are undoubtedly sensory, and others less certainly motor. The functions of the cortex vary with the area, some parts being sensory and some motor, etc.

**The cortical areas and their functions.** We will first consider the *motor area*. The general shape of the area having this function is triangular. Taking the angle between the ascending and horizontal limbs of the fissure of Sylvius as the apex, one side is extended to join the median fissure where it is cut by the parieto-occipital sulcus, and the other is extended vertically upward to join the median fissure at a right angle. This gives a triangle, roughly enclosing all the cortex that we at present know to be motor in function. The general details of this area can best be remembered by imagining the human body in miniature laid along the median border of the triangle, feet to the rear. Then we can say *in a general way* that the cortical area below each part of our model in the triangle will preside over that part of the body. In the wide head zone the upper part of the face, etc., is above, while the lower part of the face, the lips, tongue, etc., are below. The same is true of the shoulder, arm and hand centres as well as those of the leg and foot. The *sensory area* is made up of centres widely separated. For the *special senses* we saw that the cuneus of the occipital lobe was the cortical centre for vision, that the superior temporo-sphenoidal convolutions were the cortical areas for auditory impressions, the upper central part of the uncinate gyrus for olfac-



tory impressions and the inner part of the same probably for taste. The part of the cortex stimulated by the reception of impressions of general sensation is not certainly known. General cutaneous sensibility, it is claimed, and fairly well proven, is presided over by the gray matter of the gyrus fornicatus. Whether all the sensory fibres run here or not, is not proven. It is believed also by some that the sensory cortex lies just behind the motor triangle, while there are many things that point to the fact that the reception of such impressions as muscle sense, etc., is by means of cells lying in the area described as motor, in other words, that the centres of the triangle are of double function. We can only say that cutaneous sensibility is under the control of the gyrus fornicatus, and that the rest is uncertain. The frontal lobes are as yet an unknown region to us, but the little evidence that we have points to these centres as the seat of the higher mental activities, such as volition, thought, etc. (tamping-iron case.) The speech centre will be considered later.

**The corpora striata.** These are two large masses of gray matter located on either side near the centre of the cerebrum, and they have received this name from the fact that on section their gray substance is marked with white striæ (fibres). A part of each corpus striatum lies on the floor of the lateral ventricle, and this part we call the intra-ventricular portion or caudate nucleus. It is pear-shaped, with the neck extending backward. The other part, called the extra-ventricular portion or lenticular nucleus, is imbedded in the white substance of the hemisphere, and consists of three segments. Internal to the lenticular nucleus, and separating it from the caudate nucleus in front, and the optic thalamus behind, is the internal capsule, while external to it and separating it



from the claustrum, is the *external capsule*. The fibres of the internal capsule seem to have little or no communication with the cells of these ganglia. Still it is claimed that the gray matter of these ganglia, when stimulated, excite active movements of all the muscles of the opposite side of the body. In man a lesion involving the greater part of one of these gray masses has been followed by *temporary* paralysis of the opposite side, and this in turn, followed by contracture. While these facts lead us to believe that these ganglia are probably concerned in the regulation of motor impulses, perhaps even in their augmentation or inhibition, it is not claimed that the function of these bodies is in any sense proven. More recently it seems that the corpora striata are concerned in some way with heat formation. Whether irritation of these ganglia increases heat production through the muscles or in other ways is not yet certain but experimental injury in the lower animals and traumatism in man is often followed by greatly increased heat production.

**The optic thalami.** These are likewise two masses of gray matter, each lying upon one of the *crura cerebri*, and seemingly united with its *tegmentum*. They are placed, one on either side, between the diverging portions of the corpora striata. Each one forms the outer wall of the 3d ventricle, and the inner boundary of the posterior limb of the internal capsule. A part of this ganglion lies on the floor of the lateral ventricle, and the remainder sinks down in the white substance of the cerebrum to form the roof of the descending horn of the lateral ventricle. Behind on its extreme inferior aspect are the two geniculate bodies, internal and external, which join the anterior and posterior tubercula quadrigemina respectively to the optic thalamus. The posterior part of this gan-



glion is called the pulvinar, and the anterior part is divided into several nuclei. The function of this ganglion is undoubtedly sensory. The posterior part of it, we have already seen, is united with the cortical centre for vision, and very probably with the auditory cortical centre also. The tegmentum joins it below, and direct stimulation of its substance at various points gives no motor response. Clinical observation in man has shown that disease of this ganglion gives rise to disturbance of sensation on the opposite side, sometimes almost equal to hemianaesthesia. Irritation of this centre will sometimes produce hallucinations, as has been often shown by pathological growths, etc.

**The corpora quadrigemina.** The corpora or tubercula quadrigemina consist of two eminences on either side of the median line (the nates and testes) just above the aqueduct of Sylvius. We have already traced bonds of communication between them and the cerebellum, the occipital cortex, the temporal cortex, etc. The function of each pair of these twin bodies differ. Either of the *anterior* corpora quadrigemina when destroyed give as a result loss of sight in their respective half of each eye. There is also apt to be interference with the action of the ocular muscles, especially those giving the pupillary reflexes. The *posterior* corpora quadrigemina when destroyed or injured give as a result disturbance of equilibrium and inco-ordination of movement. Unilateral injury of the corpora produces what we call forced movements. In such cases movements, while executed on both sides, are not harmonious, and the victim will run in a circle, run around the fixed posterior limb, etc. It would also seem that the route of communication between the nucleus of the auditory nerve and the cortical auditory centres was by way of the posterior pair of these nuclei. The functional lines of demarcation in these bodies are not very sharply drawn.



**The other nuclei of the brain.** *The central gray tube* is the name applied to that continuation of the gray matter of the 4th ventricle upward around the aqueduct of Sylvius. Except for the nuclei of the 3d and 4th nerve that lie in it, we know nothing of its function. The same is true of the *claustrum*, that thin streak of gray matter lying external to the external capsule, and also of the other masses of cells below, the *substantia nigra*, *red nucleus*, etc., found low down in the brain.

**The white matter of the cerebrum.** In the cord we saw that the white fibres run up and down in the conducting systems, and that in the gray matter they ran from the cells of the posterior columns to those of the anterior columns, and from the cells of one side to those of the other, etc. In the brain we have the analogues of all these fibres. The afferent and efferent fibres join their respective conducting systems below, and an infinite variety of inter-central or associating fibres join the component parts of the brain. The first group of these to be considered are the fibres that cross in the *corpus callosum*. They join all the cortical centres of one side with their fellows of the other. In each hemisphere all fibres leaving or coming to the lateral regions of the cerebrum pass through that radiating mass of white matter which we call the *corona radiata*, which leads to or from the internal capsule or through the *corpus callosum*. The anterior limb of the *internal capsule* lies between the caudate and lenticular nuclei, in front of the knee, while the posterior limb extends backwards from the knee between the optic thalamus and lenticular nucleus. The function of the ant. limb is not known, but the *posterior limb* bears from before backward the following tracts : (1) Motor fibres for the face, lips and tongue ; (2) arm and hand ; (3) leg, and perhaps the trunk ; (4) sensory



fibres for all the regions mentioned above, (likewise for the opposite side) (5) the speech tract ; and (6) the crossing of the optic radiation, etc. The fibres of the anterior limb are not capable of electrical stimulation, but they degenerate when the frontal lobes are removed. The fibres that join the nucleus of the auditory division of the 8th with its cortex cannot be traced anatomically much above the corpora quadrigemina, but they are believed to run, at least in the lower parts of the internal capsule, in the sensory tract (4) described above. We know almost nothing of the function of the external capsule.

**The cerebellum and its connections.** The cerebellum, or little brain,  $\frac{1}{8}$ th the size of the cerebrum, lies underneath and at the posterior extremity of its analogue. As we have seen, it is connected with almost every column and tract in the cord through its *inferior peduncle*. Through its *middle peduncles* its two lobes are kept in intimate relationship, and through the right-angled decussation of its deeper layer it is probably connected with the nuclei of the medulla, especially the olivary body. Its *superior peduncle* brings it in intimate relationship with every part of the cerebrum. From a knowledge of these facts and from experimentation, we find that the *function* of the cerebellum is probably that of a general *co-ordinating centre*. This applies to the movements of locomotion and those of manual co-ordination especially. Experimental removal of the cerebellum in animals proves the above. Such animals are not deprived of any of the "senses," nor is muscular power impaired ; they are only incapable of making co-ordinate movements, being unable to stand, walk, fly, or execute any accustomed movement requiring harmony of action. Clinically, almost the same thing is observed in man, cerebellar disease gives



the staggering gait, and general evidence of a disturbance of the centers where "impressions of touch and position are associated with those of time and space." Forced movements are even more pronounced after injury of the cerebellum than after injury of the corpora quadrigemina.

**The membranes of the brain (and cord).** The most external is the *dura mater*, of densely matted fibrous tissue. It is the periostium of the flat bones of the skull, to which bones it is intimately adherent. Its inner surface is lined with serous endothelium, and it forms a closed cavity, being prolonged as an investing sheath on all nerves leaving the cranium and spinal canal. The space between this membrane and the next contains some serous fluid, but not very much. The next membrane, the *arachnoid*, is an open meshed mixture of yellow and white fibrous tissue, and is covered externally with serous endothelium, making the subdural space, as it is called, a true serous cavity. On its internal face the open reticular structure is continued to the *pia* and is filled with the so called cerebro-spinal fluid. The cavities containing this fluid are largest at the base of the mid. and hind brain, and act as cushions to break the force of all the mechanical shocks received in jumping, falling, etc. The *pia mater*, an open fibrous membrane, carrying the blood vessels for the cortex and following every fold of the convolutions, is the most internal layer, and insinuates itself into all the ventricles and cavities of the brain.

**The blood vessels of the brain, etc.** The *circle of Willis* is formed by a cross branch from one *ant. cerebral* vessel to the other, and by antero-posterior branches joining the *post. and middle cerebrals*. The terminal vessels of the above-named cerebrals supply the cortex of the brain, while perforating branches



from them near their origin, and from their communicating trunks, supply the region of the basal ganglia.

The *ganglionic branches* are of four sets ; (1) Those perforating branches from the ant. communicating that enter the area of the lamina cinerea, and supply the caudate nucleus ; (2) those that enter at the post. perforated space, from the roots of the post. cerebrals, and supply the optic thalamus ; (3) those from the middle cerebral (Sylvian), which entering at the ant. perforated space supply the lenticular nucleus and internal capsule (lenticulo-striate or "artery of hemorrhage") ; (4) those which leave the posterior cerebrals and pass around the crura-cerebri to supply the corpora quadrigemina and pulvinar. The *cortical branches*, which have not the slightest communication with those just given, are from the terminals of the three cerebral arteries given : (1) The ant. cerebral supplies chiefly the frontal lobes and extends back along the median line to the pre-cuneus ; (2) the middle cerebral follows the fissure of Sylvius until opposite the island of Reil, where it divides into four branches, one for the inferior frontal convolution, one for the ascending frontal, one for the ascending parietal, and one for the superior temporal and angular convolutions ; (3) the post. cerebral winds backward, giving branches to the uncinate gyrus, second temporal convolution and cuneus. The *medulla and spinal cord* are supplied *anteriorly* by the anterior spinal artery, formed by the union of two trunks which gives a vessel descending in the ant. median fissure and reinforced as it descends by branches from the vertebral, intercostal, lumbar, etc. The *medulla and cord* are supplied *posteriorly* by the two small posterior spinals, one on either side, descending and reinforced as in the previous case. The lenticulo-striate artery, referred to above and called the artery



of cerebral hemorrhage, is the largest of the Sylvian group of perforating branches, and usually ruptures near the knee of the internal capsule. ("paralysis".) The pressure here produced by the clot of rupture encroaches upon the functions of the fibres as the clot grows. This will explain the orderly onset of the symptoms so often observed in ruptures of this kind, and the inverse order of recovery as the clot is absorbed. The very small size of the posterior spinal arteries of the cord, for their length, renders them peculiarly liable at some place in their course to the endo-arteritis of late syphilis. This explains perhaps the relation between this disease and locomotor ataxia, the latter being produced by degeneration of the posterior white columns, chiefly the median column. Note the analogous seat of the lesion producing the "Argyll Robertson pupil," in both the lesion is squarely behind the central canal of the cord, i. e. posterior columns.



## CHAPTER XVI.

## ABNORMAL CONDITIONS OF THE CORD AND BRAIN.

**Perverted reflexes.** For the reaction of a *simple normal reflex* it is necessary (1) that the neuron of posterior root with its processes bearing the impulse (afferent) shall be intact; (2) that the large neuron cells of the anterior gray horn shall be functionally active; and that the connecting processes—shall be uninjured. The functional activity of the sending nerve “corpuscle” and terminal “motor plate,” etc., is taken for granted. A *radiating reflex* will occur whenever (1) the afferent impulse is sufficiently intense, or whenever the (2) excitability of the cells of the cord is unduly exaggerated. In either case, whenever the neuron of the posterior root is stimulated, impulses will pass from it not only to the anterior horn of its own, but to the horn of the opposite side as well. If both of the abnormal conditions above-mentioned exist, the radiation may extend not only as stated, but to other segments of the cord as well, and may even become general (convulsion). The cause of the *excitation* of the cells of the cornua may be (1) that they are cut off from cerebral or higher ganglionic (inhibiting) control, (2) local congestive or inflammatory irritation, (3) the influence of certain toxic agents (tetanus) or of certain drugs (strychnia). The afferent impulse in the cutaneous reflexes starts from a touch corpuscle or other terminal in the skin, and the same for the deep reflexes comes from the tendon corpuscles (muscle sense) in the tendons. The complete destruc-



tion of any of the cells or any of the fibres in the above reflex loop, abolishes the reflex on that line. *Spasm* is a symptom of excessive action of the neurons of the reflex arc. The spasm here referred to, is not that temporary discharge of nervous energy from the cortical motor areas, that we have in epilepsy, etc., but is a tonic nervous influence existing in the cord itself. Continued it gives permanent contracture of the muscles supplied from the affected spinal segments. As seen before it is usually caused by a separation of the cells of the ant' cornua from the control of the cortical motor areas above. Whether or no the peculiar views of Setschenow, that the corpora quadrigemina are the centres for the tonic inhibition of the reflexes of the cord, will be proven, is of little import. Either that theory, or the well-proven old one, that a centre released from the control of a dominating higher centre, is in a state of increased irritability, will suffice.

**Hemiplegia, etc.** From what we have seen of the origin and course of the motor impulses we can understand how a lesion of any of the motor centres of the cortex, will give a paralysis in its corresponding body part of the opposite side. (*monoplegia*.) The same is true of a lesion of the fibres in the corona radiata, the internal capsule and in the crus cerebrum. If the *lesion* referred to take place at any point *above Gubler's line*, as in the capsule, we will have limbs and face paralyzed on the same side, (*normal hemiplegia*), but if *below this line*, down to the nucleus of the 7th, we have the face paralyzed on one side and the limbs on the opposite side. (*crossed hemiplegia*.) Below this nucleus we have the pyramidal decussation and there will be paralysis on the same side as the lesion, the face not being affected at all. (*spinal hemiplegia*.)



Here motion is lost on the side of the lesion and sensation on the other side. We can readily understand this by remembering that although connected with the same side of the brain, the fibres that carry sensory and motor impulses pursue different routes in the cord. If both be considered as coming down, the motor fibres may be said to cross in the lower part of the medulla, and the sensory to cross (obliquely) at the level of distribution, lower down. The oblique direction taken by the sensory fibres as they pass over, allows quite a number of them to be cut in even a narrow unilateral section of the cord. This gives a narrow zone of anaesthesia a little below the section on the same side of the body. *Paraplegia* is the term applied to the results of a complete or bilateral section of the cord, it gives a loss of all motor and sensory conduction below the level of the section. The function of the spinal centres, below the section, are disturbed for a time, but the reflexes of defaecation and micturition ultimately return. They are, of course, unconscious acts henceforth.

**Disturbance of language, speech, etc.** To appreciate the lesions that produce these disturbances we must remember that what we call language may be conveyed either by word, symbol or gesture. Presiding over all of these motor manifestations is a cortical area, located near the face area, in the posterior part of the left inferior frontal (Broca's) convolution of the brain. Any disturbance of this area or its connections, in right-handed men, is evidenced by some deficiency in the proper formation, or arrangement of the words, by which we convey ideas. The idea of language implies that an individual has a concept, which he wishes in some manner to convey to others. He must first have his ideas, he must wish to convey them, and he must



be able to put his ideas into a sound, a sign, or a symbol, which expresses his conception to others. The inability to properly form the word or sentence, is due to some derangement of this motor language centre itself. This abnormal state is called motor or *ataxic aphasia*. Let us first consider the influence of ataxic aphasia on articulate language. We must be careful to avoid confusing the conditions here involved with aphonia or loss of voice. *Aphonia* is due to an entirely different cause, viz.: some defect in the workings of the larynx and vocal cords, usually a congestion of the substance of the cord itself, or a paralysis of the inferior laryngeal nerve that regulates laryngeal tension and control. There is no disturbance of the idea of language, for as we know, we may often read from the movements of the auxiliary lips, whatever is said. In ataxic aphasia on the contrary, there is a defect in the cerebral apparatus by which we transfer the word image which represents our idea, into such harmonious action of the muscles (of our organs of speech) as will reproduce the sound or movement we desire. To see what needs to be done here, let us first see how speech is produced. There goes out from the *word-forming centre* (Broca's convolution) a band of fibres called the *speech tract* which passes through the corona radiata, the posterior limb of the internal capsule behind the sensory fibres, and whose impulses are distributed as follows: Through the nuclei of the medulla, to the 10th cranial nerve for the vocal cords, larynx and pharynx, to the 12th for the tongue, to the 5th and 7th for the jaws, lips and soft palate. In addition to these, impulses go down the cord and through the phrenic, intercostal, dorsal and other nerves below, for the muscles of respiration. The centre that presides over the organization, distribution and regulation of these



varied impulses must be liable to derangement from its very complexity. The simplest lesion that can take place here is "blocking" of the speech-tract routes. This may be produced by capillary congestion or rupture along the line of fibres of the so called speech-tract. In this lesion there is no paralysis of the vocal cords, or tongue, or lips, or any part of the muscular system. The patient can perform the acts of mastication, deglutition, coughing, etc., which involve the muscles of this region, but he cannot properly associate his impulses to produce speech. He wishes to speak, he knows what he wishes to say, and the relation between the word representing his idea and the sound to express it is clear, and he formulates his impulses, but without avail. He can, however, as we readily see, speak by gesture or by writing. (Luke I, 20-22, and 59-64.)

The next form of lesion in ataxic aphasia is derangement of the word-forming centre itself. This may be partial or complete, *i. e.*, may be due to diminished excitability in some parts of the centre, or increased excitability, or both, or there may be complete functional loss of parts of the centre. Some patients can repeat only the vowels; in others the sounds are misplaced, as placing the last syllable of a word in the middle (inco-ordination), and in still others, the substitution of one word for another occurs (paraphasia). Some patients can repeat only a single word or phrase, often meaningless. Their vocabulary, of its kind, is more extended during anger or excitement than during quietude, the irritability of the center being then more exalted. Strangely some cases can repeat only the phrase of expression "on the mind" at the time the lesion occurred, as the expression, "I want protection," which was being pronounced as the injury was received. This



looks as if the molecular arrangement for the impulses, existing at the time, still persisted. [In some rare cases which present undoubted evidence of disease of the motor speech centre, there exists more or less inability to write, or even to gesticulate with meaning, which seems to indicate that the motor center, so-called, presides over more than simple vocal word formation, but the coordination necessary to sentence-forming of every kind as well.] There is still another form of aphasia, which we call sensory or *amnesic aphasia*. In this case the patient is devoid of language because he has lost or "forgotten" the word, character, or even movement that represents his idea. To appreciate the lesions that produce this state, we must understand that the memory of a percept is retained by the centre that receives it. The memory of things seen, characters, symbols, etc., is retained in the cells of the cortex of the cuneus, of sounds heard, words, etc., in the cortex of the first temporo-sphenoidal convolution, of movements made, as by the arm, in the cortex of control for the arm, etc. As we have seen, associating (intercentral) fibres join these centres and therefore the trouble may lie in the associating tract as well as in the centre. When the lesion lies in the first temporo-sphenoidal convolution, (left?) or its associating tract that unites it to the motor speech centre, we have what is called "*word deafness*." The patient can not speak for he does not remember the sound that represents his idea, nor can he understand spoken language, for he does not remember ever to have heard language before, his memory of words heard is lost, and all language sounds to him as foreign. He is not deaf for he will turn when called to, or for any noise. If the angular gyrus of the occipital lobe or its associating tracts is involved we have "*word blindness*." Here



the patient can talk and can see (cuneus) but as the memory of written words once seen is gone, he can not read. He may even write correctly from dictation but he can not read what he has written. His writing in this case is done by reason of memory of movements made, just as we write with the eyes shut. Any of the sensory forms of amnesic aphasia may be combined with more or less ataxic aphasia and give us mixed symptoms, very difficult to determine. Related to the above are a series of disturbances of the language centres, in which the patient is incapable of writing, (agraphia), incapable of making appropriate gestures, (amimia) or even incapable of recognizing the common objects of every day use (apraxia). The latter condition may reach such a state that he can not even recognize the usual articles of clothing worn, putting his gloves on for shoes, etc. In a case of "word blindness" in which a patient could not read by sight, (alexia), he was able to read by tracing the letters with a pen and recognizing the movements made. (The student is referred to special works on disease of the general nervous system, for the details of symptoms, and for the systematic examination necessary to differentiate these varieties of cerebral lesion.) In addition to the lesions previously described which are due to cerebral hemorrhage, embolism, trauma, etc., we have functional troubles of a kindred nature affecting the same centres. We all know that some men are fluent, and others slow talkers, but the difference in two such men is not as great as is the variation in the capacity of either of them, at varying times. A temporary amnesic aphasia attacks every speaker at times and in spite of every effort he is below his standard. This variation in the natural capacity of "speakers" is not nearly so pronounced as is their variability in the



use of gesture language. The sign language of some orators is the very embodiment of graceful expression, while others are dumb along this line. As we would expect, men are rarely equally good as writers and as speakers. *Stuttering* is not a disease of the speech centre, but is due to irritability of the nuclei of the cranial and other nerves used in phonation, especially those of the 5th and 7th. From these nuclei reflexes are radiated to the inhibitors of respiration, or to the muscles of mastication, giving the tremulous spasm of the jaw, and in severe cases to the entire distribution of the 7th, giving the facial contortions so often seen. Its relative intensity depends upon the degree of excitement of the subject, being increased by emotion, rage, embarrassment, etc. Where the impulses are sent in rhythmical order, as in singing, etc., they are never mixed. *Writers cramp*, and similar manipulative diseases, are due to essentially the same cause, the irritability and radiate spasm being due to excessive excitation of the gray matter of the anterior horn of the upper cord.



## CHAPTER XVII.

## THE SENSES.

Mental physiologists divide the senses into two primary groups or classes. These are (1) the *vague senses* (*sensus vagus*) whose impressions cannot be referred to any special end organs or nerve terminals, and cannot therefore be localized; as the senses of weariness, hunger, anxiety, etc.; (2) the *fixed senses* (*sensus fixus*) whose impressions are referable to certain special terminals or sense organs, and are thus fixed. For anatomical reasons, the latter are divided into the *somatic senses*, including the senses of *touch, temperature and muscle tension*; and the *cephalic senses* of *taste, smell, hearing and sight*. A sense of pain largely subjective, may result from overstimulation of any sensory nerve or terminal. In the excitation of the sensory terminals, a specific stimulus is required; i. e., a touch corpuscle will not be stimulated by heat, nor a temperature terminal by pressure, nor a visual terminal by sound, etc. A nerve trunk will however respond to electrical or mechanical stimulation applied at any point on its route, and not only will it respond in kind, auditory nerves giving sensations of sound, gustatory nerves sensation of taste, etc., but the response is referred to the distal (sense) terminal of the nerve stimulated. This "law of peripheral reference" is well demonstrated in cases of amputation, where the ensuing irritation of the cut nerve trunks is referred to the terminals of the lost member. In some cases of nerve lesion (locomotor ataxia) the sensation of



pain and to a less extent of touch, may be delayed (several seconds) between the receiving terminal and the perceptive centres. This is due to no disease on the part of the terminal or centre, but presumably to the impulse having to take a new route and make many "relays." Of the somatic senses, touch is largely an objective sense and temperature and pressure sense are predominantly subjective. Of the cephalic senses, taste and smell are (in man) subjective senses and sight and hearing objective. It should be borne in mind that even touch is an objective sense only when functionally pure. Thus an iron wire held against the hand gives the idea of a foreign body and a definite idea of locality, but if the wire as held be heated sufficiently to produce pain, the sensation at once becomes one of body state, and the sense of locality is largely lost. While we say in a general way that we see with the eye and hear with the ear, it must be understood that the impression is received only by the sensorium. When a sensation is felt it simply means that the sensorium is stimulated. The habit of peripheral reference makes us refer all sensations to external causes. Under certain conditions of abnormal excitability, the sensation may originate in the brain itself, but being from habit referred to an external cause, we have the hallucinations so common in cerebral disease, delirium, etc. It is a curious fact that the illusions of delirium tremens should always be of a frightful, horror-inspiring character, as of snakes, demons, etc., while the primary sensations of alcohol, opium and other stimulants that produce such mania are just the reverse, pleasant and agreeable.

**The sense of touch** or tactile sensibility is limited to no part of the body, for while varying in degree in different localities, it is present everywhere. Its



excitation is dependent upon the stimulation of the terminals in the papillæ, etc., of the skin, and the relative acuity of touch in a part is dependent upon the relative supply of terminals it receives. The theory of Weber is that the mind estimates the distance between two points touching the skin by the number of unexcited nerve endings between the points touched. The variations in tactile sensibility in the different parts of the body are made manifest by the following figures, which represent the distance in millimeters at which the points of a pair of compasses can be distinguished as separate points. Tip of tongue 1, tip of third finger 2, lower lip 4, tip of nose 6, palm of hand 10, back of hand 25, dorsum of foot 37, back of neck 50, and inter-scapular region of the back 65. The sense of locality and space comes purely as a matter of experience (Aristotle's experiment). This, with the marked increase in tactile sensibility, developed with practice, gives the wonderful manipulative power of the blind. The sense of pressure is a modification of that of touch. This should not be confused with muscle sense, although used conjointly with it. Thus, in an effort to estimate the weight of a bar of lead, we judge almost as much by the necessary amount of pressure of the fingers against it, to hold it, as we do by the degree of muscular effort put forth. The relative value of these senses can be compared as follows: Place the hand, palm up, upon a table and put in the palm of the hand a weight, now lift the hand from the table and compare the weight as appreciated by simple pressure, with the weight now appreciated by muscle sense and pressure.

**The sense of temperature** is distinct from tactile sensibility, but is like it in being general over the entire body. There are two sets of terminals in the nerve distribution of this sense, one for impressions of what



we call cold and the other for impressions of heat. The distribution of each set of terminals is punctiform, giving hot and cold "spots" of quite uniform distribution, at least as compared with the variations found in tactile sensibility. The perception of cold seems to be more intense than that of heat. To appreciate why this is true we must remember that the bulk of the human race live and die without often experiencing the influence of a medium as warm as body heat, but none have ever lived without experiencing for long periods of time a temperature lower than that of the human body, i. e. cold. If we took the temperature of the body as a standard we would be always cold, but in reality the temperature of the skin is taken as a standard, and as this varies with the medium around, we have no absolute standard. For this reason we can get accustomed to almost any temperature and in time live in comfort in any climate. This skin standard makes all estimates of heat (fever, etc.) by mental comparison fallacious. This is well seen in the following: If we place one hand in ice water ( $32^{\circ}$ ) and the other in hot water ( $110^{\circ}$ ) we appreciate fully the sensations, but if we now place both hands in warm water ( $75^{\circ}$ ) the previously cold hand will feel warm and the warm hand cold.

**The sense of muscle tension**, or as it is usually called muscle sense, is not well understood. It originates in certain nerve terminals found in the *tendons* of various muscles. These nerve corpuscles are subjected to pressure when their tendons are put upon the stretch (tendon reflexes). As we have previously seen, a part of the perceptive power referred to this sense is due to the sense of touch or cutaneous pressure. To what extent we are further indebted to a knowledge of the amount of nerve energy sent out, in executing any discriminating muscular effort, is not known.



That the amount of nerve impulse is conditionally known and regulated for each act is proven by the serious wrench to the muscles when we err in judging the weight of an object to be picked up, moved or thrown. We see the same thing illustrated in the clumsiness with which one first handles a new weapon or tool of different weight from that to which he is accustomed, or makes an unaccustomed effort with a weight or tool previously familiar for other work. So far it would seem that there was no muscle sense, but that we make use of two other functions to determine the intensity and amplitude of muscular exertion. However, if we will allow some one to take, say the hand, while the eyes are closed, and make certain passive movements with it, as tracing figures, letters, etc., we will be astounded to learn how accurately we can recognize the scope and relation of the movements made, the form and size of figures traced, etc. This is purely muscle sense, as no nervous energy was expended, nor was tactile sensibility materially involved. As stated the small pacinian-like bodies found in the tendons seem to be the terminals taking cognizance of these movements, and it is no doubt to these end organs that we are indebted for the impulses that record what we call the memory of movements made, as writing, etc. The combined sum of these "senses," is capable of wonderful achievements. All that we call higher automatic dexterity, all that comes of long and continued manual training is due chiefly to the cultivation of this group of senses, as seen in the complex movements of the violinist, etc., etc. The most interesting illustration of the use of this *sense memory* is in cases of late acquired deafness. If loss of hearing occur before adolescence, the patient will ultimately lose the power of speech ; but if it occur later the long



practice of speech makes such an impress upon the cortex, that by simple memory of muscular movements made the patient will be enabled to continue to speak, in a disagreeable but still intelligible voice.

The use of after sensations, or memory of movements made, is the means by which the blind, in whom these senses are cultivated to their highest degree, recognize by form and size, faces and other objects once known.

*Pain* is not a special sense but is in a measure the intensification of any of the senses. We use the term "in a measure," because while we say that "a loud noise hurts the ear," or "a bright light is painful to eye," the impressions produced here are not sensations of pure pain as we know them, say with the somatic senses, but are simply feelings akin. With the two most subjective of all the senses, taste and smell, the feeling is still less one of true pain. It is hard to conceive of a true gustatory or odorous impulse intense enough to produce a state of genuine pain. Hence what we know specifically as pain may be considered as due only to the intensification of the impulses of the somatic senses, tactile sensation, temperature, etc.

**The sense of smell**, if we may judge from comparative development, is perhaps the primitive sense. It is also the most delicate of the senses, particles of matter being easily detected by this sense, that are invisible by the microscope or even incapable of demonstration by the spectroscope. Camphor vapor in the proportion of one part in three billions of atmospheric air is capable of detection by this sense, while musk in the proportion of one in three hundred millions is readily discernible. To be smelled a substance must be brought in contact with, and dissolved in, the *natural fluids* covering the nerve terminals. This being true, only such substances as can be volatilized or suspended



in a finely divided state in the air can be perceived as odors. To bring the odorous gases or particles into abundant contact with the moist olfactory membrane, we sniff, or draw the air up into this part of the cavity. This sudden inspiration produces something of a vacuum in the nasal fossa and hence the incoming air is forced to find its way into the more remote *regio-olfactoria* as well as into the well travelled *regio-respiratoria*. The odorous substance must be freshly dissolved in the fluids of the membrane to be appreciated ; to be simply a soluble substance in solution will not suffice, for the nasal fossa may be poured full of an aromatic fluid (*eau de cologne*) without exciting the sense of smell.

The end organs of this sense lie in the mucous membrane of that part of the nasal fossa which lies above the middle turbinated bone, and called the *regio-olfactoria*. This membrane, often called the Schneide-rian membrane, is of a light yellowish brown tint, and is not covered with true ciliated epithelium as is the lower part of the fossa, the *regio-respiratoria*. On section it shows (1) the supporting cells, most numerous but least important, quite long columnar cells, with an oval nucleus ; (2) between these are very long and slender cells with a large nucleus and having several cilia-like rods extending from their free surface, while a delicate nerve fibre extends from the other end and joins the olfactory nerves. These long slender nucleated cells are the end organs of the sense of smell. They are quite small as compared with the supporting cells between them. Their free rodded ends are probably the real sense terminals. Under the mucous membrane we have a number of muco-serous glands (Bowman's) which secrete continuously the fluid necessary for the membrane's functional activity. In cer-



tain cases, usually of hysteria, there is marked increase in the sensitiveness of these terminals (hyperosmia). Morphine locally applied will paralyse the sense terminals, while the administration of strychnine in a less marked manner intensifies their activity. We must remember that disturbances of this sense are quite often subjective. The mutual relations between this sense and the sense of taste will be considered under the head of the latter.

**The sense of taste.** To be appreciated by this sense a substance must be in a state of solution, or at least soluble in the fluids of the mouth. The sense terminals are in the various forms of papillae on the tongue, etc., hence for taste to be appreciated the epithelium covering the tongue and its papillae must not be too thick, and the mucous membrane and terminals must be moist. In fevers, etc., the accumulation of exfoliated epithelium, dried mucus, etc., (sordes) on the mucous surfaces of the mouth almost inhibits taste. This sense is also markedly interfered with by the local influence of heat and cold, especially the former. The salts of cocaine, locally applied, also blunt it, most markedly for bitters. The principal seat of this sense is the posterior third of the tongue, the region of the circum-vallate papillae, the area of distribution of the *glosso-pharyngeal nerve*. Besides this, the anterior two-thirds of the tongue, the soft palate and its arches, and to a less extent the posterior pharyngeal wall are all endowed with this sense. The anterior part of the tongue seems to be supplied by the *chorda tympani*, while the other areas above mentioned are supplied by the *glosso-pharyngeal nerve*. The papillae of the tongue are of three kinds, filiform, fungiform, and circum-vallate. *Filiform papillae* are found over the entire surface of the tongue. They are compound



papillae in which the epithelial covering of the secondary divisions is prolonged into conical processes, often hair-like in form and structure. The capillary loops and nerve terminals are not prolonged into the secondary papillae. *Fungiform papillae*, so called from their general toadstool appearance, are larger compound papillae in which each secondary papillae receives its own plexus of vessels and nerves. They are more readily seen in children ("strawberry tongue") than in adults, and are most abundant on the sides and tip of the tongue, but are nowhere as abundant as the filiform type. The circum-vallate papillae, some twelve in number, are arranged in the form of a V on the posterior part of the tongue. They each consist of a large central compound papilla surrounded by a deep circular depression or fossa. On both the central and peripheral faces of this fossa open many of the peculiar gustatory terminals called "taste bulbs." These consist of a number of protective or "barrel stave" cells arranged around the half a dozen or more central gustatory cells, which are united with the terminals of the glosso-pharyngeal nerve. These gustatory cells have their free ends projecting from an opening in the cylinder of protective cells, and these free ends are equipped with delicate, hair-like processes (dendrites) which extend into the gustatory fossa around the circumvallate papillae. In a modified form these taste bulbs are also found on many of the lower fungiform papillae, the soft palate, epiglottis, etc.

Gustatory sensations take but four forms, viz., impressions of *bitter*, *sweet*, *acid* and *saline*. It would seem as if the four forms of this sense have each separate end organs. The acuity of taste varies with the form of sense tested, bitters being most easily detected, acids next, etc. The time required for a percept varies



also, salines here being first and bitters last, but the latter impressions are very persistent. The combined synchronous action of the senses of smell and taste gives us what is call flavor, and the various combinations of the four forms of taste with tactile impressions give us the distinctive tastes of our foods, etc. We do not appreciate to what an extent tactile and other sensory impressions are confounded with and modify taste sensations, giving the so-called cooling, astringent, gritty, oily and soothing tastes. The nerve terminals by which we receive ideas of this kind are those of the *lingual* branch of the 5th, sometimes, from its associated powers of taste, called the "gustatory" branch of the above. When one wishes to appreciate fully a taste he takes enough of the substance into the mouth to cover the surface of the tongue, lets it run back to the circumvallate area, and pressing the tongue against the roof squeezes the sapid substance into the gustatory fossae and brings it into direct contact with the processes of the gustatory cells. The galvanic current passed through the tongue gives a sensation of taste, which is acid at the anode and saline at the cathode. Subjective sensations of taste often give great annoyance, especially to the insane. Before pronouncing a taste sensation subjective, we must exclude elimination of sapid substances through the saliva, as iodides, santonin, mercury, etc. The two other special senses, those of sight and hearing, will be considered more fully.



## CHAPTER XVIII.

## THE SENSE OF HEARING.

*The sense of hearing*, may, like the sense of vision, be called a physical sense, in contra-distinction to the chemical senses of smell and taste. The registration of atmospheric vibrations for analysis and comparison demands an extremely complex apparatus and one so delicate in parts as to require absolute protection against mechanical injury. The apparatus consists of the external ear and auditory canal, the middle ear or tympanic cavity and the internal ear or labyrinth, with its canals, cochlea, etc.

**The external ear or pinna** consists of a plate of yellow elastic cartilage folded and bent on itself, with attached muscles, adipose tissue, etc., and covered with thin integument. The cartilage of the external ear is prolonged inward as a tube to form the outer two-fifths of the external auditory canal. This canal is about  $1\frac{1}{4}$  inches long and smallest ( $\frac{1}{4}$  in.) at its centre, and the floor sloping downwards both ways from the center makes this also the highest point. The canal expands a little in its vertical diameter at its outer end and expands horizontally at its inner end (speculum). Its inner extremity is closed by the tympanic membrane, which extends obliquely across it, making the front wall and floor of the canal longer than the roof and post. wall. The nerve supply of the external auditory canal is from Arnold's branch of the 10th, and the auriculo-temporal of the 5th, and inspissated wax or foreign bodies in the deeper sensitive parts of this



canal often gives unsuspected but distressing reflexes, the former nerves causing cough or even vomiting (9th), and the latter various facial neuralgias. The inner face of the canal presents the orifice of numerous ceruminiferous glands. These glands are structurally like the lower part of the sweat glands, but they secrete wax, often in considerable quantities. The muscles that move the ear are, in man, almost functionless.

**The middle ear or tympanum** is an irregular cavity excavated in the bone, just within the tympanic membrane. It is about the size and general shape of a grain of Indian corn placed on edge with the point forward. It presents six bounding walls or surfaces.

(1) *The external wall* presents the tympanic membrane set in a bony ring (*annulus tympanicus*). The *tympanic membrane* consists of three layers, an external cuticular, a middle fibrillar and an internal mucous. The middle layer consists of white and yellow elastic fibres woven like the bottom of a basket, i. e., with interlacing circular and radial fibres. The bony ring in which this membrane is stretched is incomplete at the top, and the membrane here is slack and receives the name *membrana flaccida*. In the upper half of this membrane is hung the handle of the malleus, one of the bones of the middle ear. The *chorda tympani* nerve passes like a chord across the upper segment of the inner face of the tympanic membrane, hence its name. It comes through an opening at the posterior border of the external wall, the *iter chordae posterius*, passes across the tympanum, over the handle of the malleus, and goes out through a similar opening on the front part of the outer wall, just above the opening of the *tympanic plexus*, called the *iter chordae anterius*, which leads into Hugier's canal, etc.



(2) *The internal wall* of the tympanum or middle ear presents about its centre a rounded eminence called *the promontory*, which is grooved by the branches of *tympanic plexus* of the 9th. This nerve supplies the inner and anterior wall and sends branches as follows: One to join the first branch from the geniculate enlargement of the 7th and thus form the great superficial petrosal, which joining the deep petrosal forms the vidian; another to join a smaller branch from the 7th, thus forming the lesser superficial petrosal, which joins the otic ganglia (parotid gland); and a third to join the carotid plexus of the sympathetic. At the upper back part of the promontory is a kidney-shaped opening, hilum down, called the *fenestra ovalis*, while at the lower back part is a round opening the *fenestra rotunda*. To locate these openings and get a general conception of the relations of the internal parts of the tympanum, it is well to remember that a plane which cuts in half the carotid foramen on the base of the petrous portion, and also cuts the internal and external auditory canals, will pass between the *fenestra ovalis* and *rotunda*. Just behind the openings here considered is the pyramid, which bears at its apex the opening for the tendon of the stapedius, and arching from the roof of the inner wall, down behind the pyramid, is the curved osseous canal, the *aqueductus fallopii*.

(3) *The anterior wall* presents, low down, the opening of the eustachian tube and the osseous canal of the tensor tympani muscle above it. The tube is osseous next the tympanum and cartilaginous next the pharynx (catheter). Its trumpet-shaped pharyngeal opening is dilated only during the act of deglutition (inflation).

(4) *The posterior wall* presents the openings of the mastoid cells, both large and small, but both lined by the continuation of the mucous membrane of the tympanum (mastoid disease).



(5) *The inferior wall*, or floor, presents only the opening of entrance for Jacobson's nerve, giving the tympanic plexus above described.

(6) The *superior wall* or roof presents nothing of interest, only a thin plate of bone separating it from the cranial cavity above.

*The auditory ossicles*, three in number, are called respectively the malleus, incus and stapes. *The malleus*, the most external, as we saw before, has its long process or handle woven into the middle layer of the tympanic membrane, and this imparts a motion to the malleus which, by an interlocking union, is transmitted to the incus, thence to the stapes, and by the "foot piece" to the perilymph of the internal ear. From the neck of the malleus there runs forward a ligament ("laxator tympani" ?) which passes into the glasserian fissure. A part of this ligament is always ossified, forming the processus gracilis of the malleus.

From the neck of the malleus there runs backward in the membrana tympani a thickened fold of this membrane, forming a functional analogue to the anterior ligament. Around these ligaments as an axis the malleus rotates, so that when the manubrium goes in the head of the bone moves out and vice versa.

*The incus* lies next the malleus and between it and the stapes. It is fastened by an interlocking union, and a uniting ligament, to the malleus, and by a short thick ligament, extending back from its short process, to the posterior wall. The union with the malleus is a peculiar one, a sloping cog fitting into a socket, so that to move the handle of the malleus inward causes a similar movement of the incus, but an outward movement of the malleus causes no change in the other bone. This allows distention of the middle ear without damage to the attachment of the stapes (effusion).



*The stapes*, shaped like a stirrup, is the most internal of the auditory ossicles. It is united by a capsular ligament to the long process of the incus and its base is fitted into the *fenestra ovalis*, to the margins of which it is attached all around by an annular ligament, but *most strongly at the front end*.

*The muscles of the ossicles* are two, the *tensor tympani* and *stapedius*. The first, supplied by the 5th through the *otic ganglion*, draws the handle of the malleus, and with it the *tympanic membrane*, inward. This couples the interlocking action of the malleus and incus, and also by a variation in tension gives a varying fundamental tone to the membrane, etc., etc. The second muscle the *stapedius*, supplied by the 7th, draws the neck of the *stapes* backward, and this in turn moves the base. As, however, from its relative fixity the anterior part of the base cannot move, when the neck comes back the posterior part of the base necessarily moves in and compresses the fluid of the internal ear, in a degree proportionate to the tension of the muscle.

**The internal ear or labyrinth** lies just internal to the *tympanic cavity*. It consists of a central portion or *vestibule*, a posterior portion formed of the three *semi-circular canals* and an anterior portion or *cochlea*. The *cochlea* is primarily the auditory part of the ear, the canals the part chiefly concerned in equilibration, and the *vestibule* is curiously concerned in both. The *osseous labyrinth* has within it a more or less exact membranous imitation of its external form. This enclosed membranous labyrinth is filled with a mucoserous fluid called *endolymph*, while around the membranous labyrinth, and between it and the *osseous wall*, is the *perilymph*.

*The vestibule* is an excavated cavity in the bone



having the same general shape as the tympanum, but smaller, and having the following limiting walls. (1) The outer wall which presents the *fenestra ovalis*, filled in by the base of the stapes, its annular ligaments, etc. ; (2) the internal wall presents a rounded depression (*fovea hemispherica*) with numerous perforating foramina (*macula cribrosa*), and the opening of the *aqueductus vestibuli* ; (3) the posterior wall presents the five openings of the three semi-circular canals ; (4) the anterior face presents the large opening of the *scala vestibuli* ; (5) the roof bears another perforated depression (*fovea hemieliptica*) ; and (6) the floor shows in front the posterior extremity of the *lamina spiralis*.

*The semi-circular canals*, three in number, are located above and behind the vestibule. They are of very unequal length, but each describes a little more than half of a circle. One end of this semi-circle is dilated to about twice the diameter of the rest of the tube, and called the *ampulla*. The canals lie in such relation to each other that each one is at right angles to the other two and yet at the same time a canal on one side of the body is always in a plane parallel to that of some canal on the opposite side. The six canals in other words lie in but three planes and these planes represent the three dimensions of space. The superior canal, roughly parallel to the sagittal plane of the body, has its ampullated end opening free in the upper part of the vestibule, but its other end is common with the posterior canal next mentioned. The posterior canal, with a general direction in the transverse plane of the body, has its ampullated end opening into the lower part of the posterior wall of the vestibule, the other joining the superior canal. The horizontal canal is the smallest of the tubes, and has two distinct openings. The ampullated end is just external to the upper open-



ing of the superior canal and the other just external to the common orifice.

*The membranous labyrinth* of the canal consists of a membranous tube loosely filling each canal, but dilated (ampullated) and closely adherent to the bone at the ampulla. At each end these membranous canals are joined to a membranous sac, called the utricle, which lies in the posterior end of the vestibule. This utricle is joined by a Y-shaped tube to a smaller membranous sac, in the vestibule, called the saccule, the third end of the Y-tube passing through the aqueductus vestibuli. A small tube, the canalis reuniens, now unites the saccule with the scala media of the cochlea. Histologically the membranous labyrinth consists of three dissimilar layers, the external having fibrous processes on its outer surface by which the canals, utricle, etc., are anchored to the bony walls around them and supplied with nutrition; and the inner layer consisting of secretory cells, which secrete the endolymph. The middle layer, called the tunica propria, forms the chief element of the membranous walls of the canals and sacs. The vestibular branch of the 8th sends divisions to each ampulla of the semi-circular canals, and through the macula cribrosa to the saccule and utricle, which end as follows: In each ampulla there projects from one side of the membranous canal an elevation from which a series of fine hair-like rays extend into the cavity of the ampulla. This elevation is called the crista acustica, and each hair-like ray is united with a terminal fibre of the vestibular nerve. In the utricle and saccule we have a nerve terminal equally elaborate, here called the macula acustica. It is less elevated than the other, and has entangled in its hair-like processes amorphous and crystalline particles of carbonate of lime to which the term *otoliths* is applied. The func-



tion of these beautiful terminals seems to be as follows : The endolymph by reason of its mobility is free to move in the canals, so that when any movement of the head is made in the plane of any canal, the endolymph (of that canal) by reason of its inertia seems to flow against the movement. This causes a streaming of the endolymph through the hair cells, [which cells, of course, move with the head,] and a stimulus is thereby imparted to the nerve endings in the hair. When a movement in a given plane is long continued, the endolymph of the canal in that plane is finally set in motion and this motion continues after that of the body ceases, giving a sense of vertigo as seen in children who turn around till they "get drunk." By the movement imparted to this fluid and its influence on the vestibular terminals, we are enabled to judge of our relative position and plane of movement in any act, as compared with a previous position and course. The loss of this function produces marked disturbance of locomotion, as seen in the condition called Meniere's disease.

*The cochlea* consists of a cavity in the bone, of very peculiar shape and formation. It is formed as if a conical tube were coiled, like a snail shell, two and half times around a central axis. It is placed in front of the vestibule and its central axis or *modiolus* is in the line of prolongation of the internal auditory canal. This tube, as it winds around, is divided into two parts by a septum partly osseous and partly membranous that extends along its lumen from the base almost to the apex of the coil. This septum is called the *lamina spiralis*. Its inner half, or half next the central axis, is composed of a spiral ridge of bone the *lamina spiralis ossea*, which projects out from the inner wall of the canal, as if to divide it in half. The external portion of this septum is a thin fibrous mem-



brane, called the *membrana basilaris*, and it extends from the osseous lamina to the outer wall of the canal, to which it is attached by the *ligamentum spirale*. This septum, as stated, extends from the base of the coil almost to the top, and divides the tube into two canals, an upper or *scala vestibuli*, and a lower or *scala tympani*, which are in communication through the undivided part of the tube, at its apex, called the *helicotrema*. The lower end of the *scala vestibuli* opens directly into the vestibule (observe the names), and the lower end of the *scala tympani* abuts against the (internal) tympanic membrane, that closes the *fenestra rotundum*, and thus separates this canal from the middle ear. Both of these canals are filled with perilymph continuous with that of the vestibule. There lies upon the outer part of the osseous lamina spiralis a cartilage-like mass, the *crista spiralis*, from the upper surface of which there springs a membrane (Reisner's) which extends upward and outward to join the external osseous wall of the canal and cut off a portion of the *scala vestibuli* as a separate canal, the *scala media* or *ductus cochlearis*. This latter canal, extending from the inferior origin of the lamina spiralis to the *helicotrema*, becomes larger as it ascends, is filled with endolymph through the *canalis reuniens*, and contains the *organ of corti*. This organ lies upon the *membrana basilaris* and includes as a central feature the so-called *tunnel of corti*. This tunnel is formed of inner and outer rod-shaped cells which rest upon the basilar membrane and lean against each other at the top, like the rafters of a house, leaving the triangular tunnel below. On either side of this column of rod-shaped cells, which form the tunnel, we have a line of *hair cells*, the inner row being single, and the outer row triple, while both have the slant of



corti's rods, inner and outer respectively. These hair cells have hair-like processes extending from their upper surface, and these project through suitable openings in a fenestrated membrane, the *membrana reticularis*, which overlies the hair cells. Above this, extending outward from the *crista spiralis*, is a heavy dense membrane the *membrana tectoria* which touches the tips of the hair-like processes of the hair cells, and seems to act as a damper to excessive vibration.

*The cochlear nerve* comes with the vestibular branch through the foramina at the extremity of the internal auditory canal. Here the nerve passes through a tubular opening in the *modiolus*, in the osseous central axis of the cochlea, to give off fibres to the organ of corti as follows: As the nerve ascends in the central canal of the modiolus branches pass out through radiating perforations in the osseous lamina spiralis, to emerge under the *crista spiralis* and supply with terminal fibres the inner hair cells, while others passing between these cells and across the tunnel supply also the outer hair cells. In cavities excavated for them in the substance of the osseous lamina, these nerve fibres present a ganglionic enlargement, the so-called *ganglion spirale*.

*The function* of the various parts of the auditory apparatus here given may be briefly summarized as follows: Sound waves coming through the external auditory canal, etc., produce sympathetic vibrations in the tympanic membrane. All sound waves cause vibration of the tympanic membrane, but naturally it is most affected by those tones which correspond with its own fundamental tone or its octaves. But as we have seen the action of the *tensor tympani* gives it a variable fundamental tone, and in addition the ossicles act as a damper preventing excessive sympathetic vibration. The vibrations are conducted through the



chain of ossicles, and the tympanic membrane being many times (30 to 1) larger than the base of the stapes, these vibrations are intensified in power and are thus transmitted to the perilymph. If enclosed solely in the rigid osseous walls of the labyrinth, noncompressible fluids like the peri- and endo-lymph when subjected to pressure and vibratory forces, would do great damage to the delicate structures of the organ of corti, ampulla terminals, etc. The secondary tympanic membrane closing in the fenestra rotunda, by its elasticity obviates this difficulty, and vibration waves transmitted from the base of the stapes are conducted through the perilymph of the scala vestibuli to the helicotrema and around through the scala tympani to the terminal tympanic membrane. By these waves the membrana basilaris, etc., is thrown into sympathetic vibration which is greatest at the point whose fundamental tone accords with the wave. This vibration is thus analysed and registered by the terminal hair cells of the organ of corti, and the impulses generated pass through the cochlea branch of the 8th to the posterior nuclei of the same. It is probable that they then pass over to the opposite side and up through the tegmentum to the (inferior levels of) the posterior limb of the internal capsule and hence through the corona radiata to the cortex of the superior temporo-sphenoidal convolution. Here the impulse is "perceived" and the memory of the percept is stored in the some centre that received it. Irritation of this cerebral auditory centre will produce subjective impressions of sound which are referred to an external source, and in some cases give rise to dangerous hallucinations. The power of the internal ear to analyze and differentiate sounds makes its possessor sensible not only to the beauties of harmony, but in equal measure to the agonies of discord.



## CHAPTER XIX.

## THE SENSE OF SIGHT.

This is the sense that never rests while man is awake. A man may practically rid himself of disturbing sounds, smells and tastes, and still pursue his regular vocation, but so long as he is engaged in anything requiring the use of the eye at a focal distance of less than 20 feet, the eye is engaged in muscular effort. This "eternal vigilance" explains the frequency with which neuroses result when the eye is so diseased or so constructed as to require more than ordinary muscular effort in the performance of its functions.

We will take up first the appendages of the eye, and then the organ of vision itself.

**The appendages of the eye.** These are the lids, the lachrymal glands, the lachrymal sac, with its various canals, etc., the external eye muscles, etc. The functions of these accessories are so intimately related to the function of the eye itself and so necessary to its perfect working, that it will profit us to go into detail.

*The lids.* A vertical section of the lid shows us from before backward (1) the *integument*, thin, almost hairless and devoid of subcutaneous fat; (2) the transverse section of the fibres of the *orbicularis palpebrarum*, differentiated near the margin into the muscle of *Riolanus* (entropion); (3) the *tarsal plate*, a thick dense fibrous membrane curved to fit the eye ball, containing in the substance of its posterior layer the *meibomian glands* and covered internally with a vascular membrane the *conjunctiva*. The *meibomian glands* consist of



long tortuous central tubes joined by lateral ducts ending in sacculated glands, sebaceous in character (chalazion). The oil here secreted prevents the overflow of the tears. Mohls' glands, modified sweat glands, open between the cilia or eye lashes and the mouths of the meibomian glands (hordeolum).

*The lachrymal gland* lies in the upper outer part of the orbit, suspended from the periostium above and resting upon the eye ball below. It resembles a serous salivary gland in structure, and its half-a-dozen or more ducts open in the upper conjunctival cul-de-sac. The saline fluid (tears) secreted by this gland passes down over the front of the ball and keeps moist and healthful its delicate surface. The excess of tears are removed by the drainage apparatus below given.

*The lachrymal canals* begin as two minute openings, the puncta lachrymalia, seen at the junction of each lid with the lacus lachrymalis. From each of these orifices two small canals or *canaliculi* run outward to join the *lachrymal sac*. This sac, lodged in the osseous lachrymal groove, is continuous with the lachrymal duct below, which opens into the inferior meatus of the nose, where its mucous membrane forms a valve-like fold (Hasner's). The sac and duct are composed of a fibrous elastic coat, with an internal mucous membrane, continuous with the mucous membrane of the nose. This sac is compressed periodically by the action of the orbicularis palpebrarum and tensor tarsi (Horner's) muscle, but the outflow of the tears seems chiefly due to siphonage.

*The external muscles of the eye.* We will first consider the orbicularis palpebrarum (7) which performs the periodic act called "winking." This act, as we saw, not only aids in emptying the lachrymal sac and favors aspiration of the tears through the puncta, but



it also passes the margins of the lids over the cornea, moistening it and removing any dust or adherent particles. This periodic act is a reflex one, excited through the ciliary and other nerves. It is also a voluntary act, but if the above nerves, or the optic nerves, be intensely stimulated it is involuntary and beyond control (blepharospasm). The elevation of the upper lid is by means of the levator palpebrae (3), while the lower lid falls by gravity. In looking downward the action of gravity is here supplemented by the action of the inferior rectus, whose tendon of insertion is connected by a few fibres with the tarsus of the lower lid.

The true ocular muscles are the four recti and the two obliques. When the eyes are at rest the muscles are in a state of elastic equilibrium. When the eyes move in any direction from this state of rest they move under the guidance of the above mentioned muscles, the external rectus (6) producing outward rotation and the internal rectus (3) inward, etc. As the axis of the orbit in which the eye ball rests, does not coincide with the visual axis of the eye, any movements, other than the two given, must be made by the conjoined action of two or more muscles ; as upward by the sup' rectus (3) and inf' oblique (3), downwards by the inf' rectus (3) and sup' oblique (4), etc.

**The eye**, or as it is called the "eye ball," consists of several layers or tunics. The most external of these includes the *sclerotic* and its transparent prolongation the *cornea*. The second layer, or tunica uvea, includes the *choroid*, the *ciliary bodies* and the *iris*. The internal layer embraces the *retina* and its anterior prolongation the *pars retinae ciliaris*. Within the latter, and in front of it, we have the refracting media or humors of the eye ; the *vitreous humor*, the *lens*



and its *capsule* and the *aqueous humor*. These, with the vessels of nutrition, and the nerves of the control, make up the eye.

The *Cornea*, whose diameter represents about one-sixth of the periphery of the globe of the eye, is composed of five layers, from before backward, as follows : (1) An epithelial layer, the continuation of the stratified squamous epithelium of the conjunctiva, supported on a more or less columnar layer below. (2) The anterior elastic layer (Bowman's), a thin structureless basement membrane. (3) The substantia propria of the cornea, which layer comprises nine-tenths of its thickness. This layer consists of a series of open connective tissue membranes superimposed upon each other with inter-communicating lymph spaces between them. These lymph spaces are filled from the lymphatics of the conjunctiva, and in each of the spaces lies a branched corneal corpuscle. Nerve fibrils ramify in the substantia propria, some perforating the anterior elastic lamina. (4) The posterior elastic (Descemet's) layer bears a very close resemblance to the anterior elastic, but is more dense and resistant. At its periphery this lamina breaks up into a series of radial fibres, some of which are prolonged backward to form the tendon of origin for the tensor choroidae muscle, and others turn inward to form the connective tissue support of the iris or ligamentum pectinatum iridis. (5) The last or most internal layer is the endothiloid layer of single cells lining the inner face of the above. At the junction of the cornea and sclerotic, and just external to the peripheral sub-division of Descemet's membrane, is the circular peripheral lymph canal of the cornea (Schlemm's), and just external to it in the sclerotic is a venous plexus. Openings through the radiating fibres of the posterior elastic lamina, called the for-



mina of Fontana, connect the canal of Schlemm with the anterior chamber of the eye. (drainage angle.)

*The Sclerotic* forms the outer envelope of the eye and is a dense white fibrous tunic, thickest at the corneo-scleral junction. Behind, its outer layers are continuous with the sheath of the optic nerve while the internal fibres are continued as an open net work across the opening of the optic nerve forming the lamina cribrosa. The sclerotic (and cornea) is normally almost spherical, but is long in its antero-posterior diameter in myopic or "near-sighted" eyes; and is relatively short in hyperopic or "far-sighted" eyes. It receives the insertion of the recti and other eye muscles and is poorly supplied with blood vessels and nerves. Having considered the outer tunic we take up the middle coat or tunica uvea. This as before stated includes the choroid, the ciliary bodies, with their contained muscles, and the iris.

*The Choroid.* This layer lies inside the sclerotic and extends forward as far as the ciliary bodies, with which it becomes continuous. It is not continuous over the opening of the optic nerve behind and it is this circular opening in the choroid, which produces the so-called *optic disk*. The choroid is composed of the following layers: 1. The thin external layer or *lamina supra-choroidea* perforated by lymph channels and having large lymph spaces on both its external and internal face. 2. The *substantia propria*, a layer of large blood vessels and elastic fibres. In this, the thickest layer of the choroid, runs the long posterior ciliary arteries forward to their point of distribution, and here also are the larger branches of the short post-ciliary arteries and the ciliary or vorticose veins. Pigment cells are scattered throughout its substance and externally we find large lymph spaces lined with endo-



thelium. (3) The dense *limiting membrane* that separates the above from the following. (4) The *chorio-capillaris* a layer containing the plexus of small capillaries from the short posterior ciliary arteries which pierce the above limiting membrane for the nutrition of the internal parts of the eye. It is more or less pigmented and is separated from the retina by (5) the hyaline layer or *lamina vitrea*. The lymphatics of the choroid are in the outer layers, where they nourish also the sclerotic. They pass out around the vorticose veins and are continuous with channels which lie in the optic sheath. The "aqueous" from the vessels of the *chorio-capillaris* passes inward and then forward to the anterior chambers of the eye, etc.

The *Ciliary bodies*, which contain the ciliary or *tensor choroidea muscle*, are the anterior continuations of the choroid. This ciliary muscle arises at the corneo-scleral junction from the tendonous processes of the posterior elastic lamina of the cornea, and in interrupted bundles extends radially backward to end in the elastic fibers of the *substantia propria* of the choroid. When it contracts it stretches and draws forward the anterior portion of the choroid and all attached parts, hence its name. Besides these muscular fibres a few others, especially marked in hypermetropic eyes, run around the inner face of the eye at right angles to the course of the other fibres. This gives a somewhat sphincter-like muscle called *Muller's muscle*. The remainder of the ciliary bodies that exist are continuations of the choroid, but the *substantia propria* is thinner and more pigmented, the internal limiting layer and *chorio-capillaris* have largely disappeared and the *lamina vitrea* is thicker and more dense. Internal to this is the *tapetum nigrum* of the retina and the *pars ciliaris retinae* to be considered later.



*The Iris*, also a part of the uveal tract shows on section from before backward the following parts: (1) An endothelial layer, flat polyhedral cells which in dark eyes contain some pigment. (2) An open basement membrane the continuation of the ligamentum pectinatum iridis. (3) The substantia propria iridis, continuous with that of the ciliary bodies and choroid. This contains the peripheral and the marginal plexus of capillaries and the muscles of the iris. One of these consists of circular muscular fibres disposed on the posterior surface of the pupillary border of the substantia propria, and called the *sphincter pupillae*. The other is composed of scattered radiate muscular fibres and called the *dilator pupillae* as well as abundant yellow elastic fibres radially arranged. (4) A basement membrane continuous with the lamina vitrea of the choroid, etc. (5) The pigmented epithelium of the tapetum nigrum and containing the pigment cells that give color to the iris. All these layers are devoid of pigment in albinos.

*The Retina*. This membrane contains the functional end organs of the sense of vision. It is composed of nerve fibres and terminals, which are arranged as follows: The optic nerve leaving the chiasm passes forward and enters the eye through the perforations in the lamina cribrosa where the various nerve fibres spread out radially over the inner face of the choroid as a membrane. If we will take a single nerve fibre and follow it we will get a clear conception of the structure of the retina. After leaving the optic disk this fibre will be found to run outward under the internal limiting membrane of the retina, to the appointed place. Here it turns towards the choroid and expands into a ganglion cell giving off filaments which now pierce a thick layer of granular tissue held in a



reticulum of connective tissue continuous with the internal limiting layer before mentioned. The nerve filaments, which are to form the rods and cones of the eye, now expand into smaller ganglion cells, pierce another granular layer, like the first but thinner, expand again into oval ganglion cells, pierce a very thin external limiting membrane and end alternately as rod-shaped or cone-shaped cylinders, whose ends are embedded in the pigment of the simple polygonal squamous cells which form the external layer of the retina, the *tepetum nigrum*, which rests on the choroid. Counted from within outward this gives the classical ten layers of the retina. This arrangement exists over the entire retina except at the following points: (1) Just behind the ciliary bodies the nervous elements of the retina end in an irregular jagged line forming the so-called *ora serrata*. Beyond this only the connective tissue elements of the retina continue forward as the *pars ciliaris retinae* and as the *tapetum nigrum*. (2) In the optic disk only nerve fibres are found; hence we have here no power of vision, and this give us the "blind spot" of the eye. (3) At a point four millimeters to the outer (temporal) side of the centre of the optic disk is a tawny yellowish spot called the *macula lutea* and about its centre a depression the *fovea centralis*. In the fovea of man no rods are found, only cones, and these are more slender than elsewhere. To produce the relative thinness of the retina at this point all the internal layers are reduced in thickness. This area is functionally the most active of the entire retina. The rods (and cones) of the retina during life contain in their terminals a peculiar pigment, which they seem to extract from the pigment cells of the *tapetum nigrum*, called *rhodopsin* or visual purple. Darkness seems necessary to its formation, and when abundant



the eye is most sensitive to light. The retina is supplied with nutriment through the arteria centralis retinae, a small vessel which pierces the optic nerve and lamina cribrosa and about the centre of the optic disk divides it into five or six branches which subdivide and ramify in the inner layers of the retina. No large branches run in the region of the macula lutea. This artery forms no anastomosis with neighboring vessels and its blood is returned by veins that accompany the arteries. In foetal life a branch of this artery, called the lenticular artery, extends from the centre of the optic disk to the posterior face of the lens. It passes through the vitreous and should the artery fail to atrophy it seriously affects vision.

*The Lens* or crystalline humor of the eye lies just behind the iris and separates the aqueous from the vitreous humor. It is clear biconvex solid body having an equatorial diameter of about nine millimeters with a radius of curvature for the anterior service of about eight, and for the posterior service of about six millimeters. It is composed of cellular lens fibres and interstitial substance. The fibres are chiefly on the surface and are bent over the border of the lens to meet on either face in triradiate lines. Each lens fibril is hexagonal on section, from pressure, and seems to consist of an external envelope containing globulin. The nuclear or central portion is more dense than the cortical portion and less fibrillar. The combined action of these elastic fibres bent over the margin of the lens makes it tend to expand antero-posteriorly and of course contract equatorially. The lens is encased in a delicate transparent capsule of epithelium thicker in front, especially at the margins of the front surface. At this thickened anterior border the radiate suspensory ligament of the lens, or the zonule of Zinn, is



attached. This ligament is the anterior prolongation of the pars ciliaris retinae, which is intimately adherent to the inner face and apex of ciliary bodies, from which point it is reflected radially inward to be attached to the capsule of the lens as stated. It is not a solid membrane, the alternate elevations of the ciliary processes making it rather a series of radiate ligaments.

*The Vitreous humor* of the eyes fills the entire cavity of the globe behind the lens. It is bounded peripherally by a thin clear *hyaloid membrane* which lies on the retina behind, and on the pars ciliaris retinae, more anteriorly. When the ciliary bodies are reached this membrane is carried direct to the posterior surface of the lens and does not touch the suspensory ligament of the lens, except at the periphery. Thus a space is left between the hyaloid membrane and suspensory ligament around the border of the lens and this forms the canal of Petit. Within the hyaloid membrane is the substance of the vitreous, an albuminous jelly containing a few isolated branched cells and irregular connecting fibrils (*muscae volitantes*). There is a wide tube of hyaloid membrane extending through the humor from the optic disk to the posterior face of the lens. This produces the canal of Stilling, is filled with watery fluid and must not be confused with the foetal canal for the lenticular artery.

*The Aqueous humor* fills all the chambers of the eye lying in front of the lens, etc. The large space situated between the cornea in front and the iris and lens behind is called the anterior chamber, while the smaller space lying between the iris in front and the zonule of Zinn behind is called the posterior chamber. Both of these are filled with aqueous humor which, unlike the vitreous, is not a fixed "humor" but is renewed regularly by flow from the ciliary vessels be-



hind and discharges in front through the foramina of Fontana and the canal of Schlemm. This humor is a clear, slightly albuminous fluid, closely resembling a diluted lymph. It transudes from the iritic and ciliary vessels, percolates through the canal of Petit and enters the posterior chamber of the eye. Here some percolates through the open structure of the iris, but the bulk of it passes through the open pupillary aperture and makes its way outward to the corneo-scleral duct or canal of Schlemm, whence it empties into the adjacent plexus of vessels.

*The Blood vessels of the eye*, consist of the arteria centralis retinae previously mentioned and the posterior and anterior ciliaries. (1) The posterior ciliaries are two, the long posterior and short posterior. The latter some dozen or more in number, are derived from the ophthalmic, and pierce the sclerotic around the optic nerve. They run forward in the substantia propria choroidae giving off small vessels to the chorio-capillaris as they go. They finally supply the ciliary bodies and anastomose with the vessels of the iris, etc. The long posterior ciliaries two or three in number arise from the same source, pierce the sclerotic just external to the preceding and run forward in the choroid, external to the others, to supply the iris and contiguous parts. (2) The anterior ciliaries, derived from the muscular branches of the ophthalmic, pierce the sclerotic just external to the corneo-sceleral junction and give blood to the iris and ciliary bodies. The blood from all these vessels is gathered into the four venae vorticoseae which pierce the sclerotic and emerge about the antero-posterior equator of the globe, to join the ophthalmic veins.

*The Nerves of the eye are* ; (1) The optic, which is the nerve of the special sense of vision and also contains



excito-reflex fibres for the pupil and lids, etc.; (2) The short ciliary nerves, some six or eight in number, run from the ophthalmic ganglion to pierce the sclerotic around the optic nerve, run forward on its inner surface and are distributed to the ciliary muscles, iris, etc. (3) The long ciliary nerves, two or three in number come direct from the naso-ciliary branch of the 5th, join the short ciliaries and proceed with them to their point of distribution. The fibres of those nerves that come from the 3d cranial, supply with motion the ciliary and sphincter pupillae muscles, those from the sympathetic, supply motion to the dilator pupillae, and those from the 5th, furnish sensation, etc., to the entire eye. The exact relation of the ganglion to the short ciliaries is not well understood. The *centre* for the control of *pupillary contraction* (excluding the cortex) is the nucleus of the 3d nerve in the aqueduct of Sylvius. The route of its reflex action is through the optic, to the ant' corpora quadrigemina, through intercentral fibres to the nucleus of the 3d cranial and thence through it to the sphincter. The *centre* for the *dilation of the pupil* lies in the dorsal cord. Impulses from this centre pass out by the rami communicantes and up through the cervical sympathetics. Impulses from the cerebral cortex of control pass down (in the face tract) to the centres mentioned.

**The refractive power of the eye** is such that, when it is absolutely at rest, parallel rays of light, entering the eye and pupillary opening and passing through the lens, are refracted to form an image, of the object viewed, on the macula lutea and surrounding retina. Here they produce such chemical changes in the pigment of the retina as will stimulate the appropriate retinal terminals and produce impulses in the optic nerve. This refractive condition exists only for par-



allel rays. Rays entering the pupil from a distance of twenty feet and beyond are practically parallel. Rays from a point nearer than twenty feet (or diverging rays) must of necessity (in such an eye at rest) be focussed behind the retina, giving imperfect or no vision. If the eye could be lengthened, of course the retina, could be brought to the point of focus. We are, however, provided with an apparatus by which we can change the curvature of the lens and thus its focal distance, accommodating the eye for an object at practically any distance.

*The mechanism of accommodation* is as follows: The ciliary or tensor choroidae muscle, when stimulated, stretches the elastic choroid and draws the ciliary processes forward towards its point of origin. This, with the action of the circular ciliary (Muller's) muscle, relaxes the suspensory ligament of the lens and its inherent elasticity causes it to bulge forward, changing in curvature and focus. When the action of the ciliary muscles ceases, the elastic choroid draws back the ciliary processes, tightens the suspensory ligament and compresses the lens to its previous curvature. The increased curvature of the lens brought about by the act of accommodation is called the accessory meniscus of curvature. (3. D.) When the eyeball is too short (hyperopia or far sight) even parallel rays are focussed behind the retina and muscular accommodation must be used at all times, producing eye strain, headache, etc. When the eye ball is too long (myopia or near sight) parallel rays are focussed in front of the retina and only fall on the retina when the object viewed is brought near. When one becomes forty or more years of age the lens fibres begin to lose their elasticity and the lens will not change its curve even when its ligament is relaxed but remains set in a con-



dition to focus parallel rays only (presbyopia). To enable such persons to see near objects, read, etc., we give a glass equal to the accessory meniscus of curvature needed for such work when young. The lens for the relief of far-sight must be convex (+) and that for the relief of near-sight must be concave (—). The anterior surface of the cornea (or lens) should present the equal curvatures of a segment of a sphere. If the radius of curvature of the cornea in one meridian be greater or less than in the other, the lens will not bring the rays to a point and we have the condition known as astigmatism. A cylindrical lens, that is one cut from the inner (—) or outer (+) surface of a hollow cylinder will correct this refractive error, as the rays are focussed in front or behind the retina respectively.

**The relation of the eyes to each other.** The *visual* (antero-posterior) *axis* of the eye, is a line prolonged from the fovea centralis through the nodal point of the lens and the vertex of the cornea. Where this line pierces the cornea and sclera it establishes the anterior and posterior poles of the eye, respectively. All movements of the eye are made around a point two mm. behind the centre of the visual axis called the "point of rotation." The transverse axis of the eye is a line prolonged through the point of rotation of both eyes. The vertical axis passes through the point of rotation at right angles to the visual and horizontal axes, respectively. Planes passing through these axes divide the eye by vertical, horizontal and equatorial sections. The position of rest, (muscular equilibrium) is when the visual axes are parallel with each other and with the sagittal plane of the body and are in the same horizontal plane. To keep the visual axes fixed on any point, even at infinity, the visual axes must converge



and the nearer the point the greater the convergence till the "near point of convergence" is reached. This convergence is frequently combined with an upward or downward movement. The nerve action for all such movements must be harmonious, and for this reason a single nerve (3d cranial) supplies the muscles of pupillary contraction, accommodation, convergence, etc. This is an "associated movement" and is greatly simplified by unity of nerve supply. Conversely the movements of divergence, pupillary dilation, etc., which bring about the condition the reverse of this (viz., distant vision) are brought about by varied nerve impulses. The less frequently used muscles of rotation (obliques) also have different sources of nerve supply.

*Binocular vision* is of service in that it increases the field of vision, gives perception of depth, and also allows estimation of size and distance. The formation of the eye, so that corresponding points of the retina will be stimulated by rays of light from the same point in the field of vision, allows binocular vision.

If we could, without other disturbance than lateral shift, place one retina immediately over the other, we would find that while the optic disks (blind spots) would not coincide practically all other points would. In other words the light rays from the (experimentally) now single lens would pierce the transparent retinae at practically the same points as if each were in its own globe. Moreover, while separated for a time, anatomically the fibres unite in the same tract and impulses from these coincident points go ultimately to the same cortical centres. Here by experience the images, although differing as they must from differing points of view, etc., give rise to a single percept.

This slight difference in the respective images from different points of view, gives us stereoscopic vision and all the benefits that arise from it.



**Color perception.** We have reason to believe (Young-Helmholtz theory) that the retina contains three sets of terminals for the appreciation of rays of the three primary colors,—*red, green and violet*. The mingling of these rays in varying proportions, would produce stimulation of the terminals in varying degrees of intensity, and give perceptions of all the shades of color. If the terminals of one color be stimulated for quite a time, these terminals become fatigued and if we then shut our eyes we will receive feeble impressions from the terminals of the complementary color, which are not fatigued, but apparently excited. Thus we attempt to explain the after sensations of color so often seen. The absence of terminals for the appreciation of red is marked in that part of the retina near the ora serrata. When from congenital or acquired causes (tobacco, etc.), defective color perception extends over the remainder of the retina we have what is called "color blindness."

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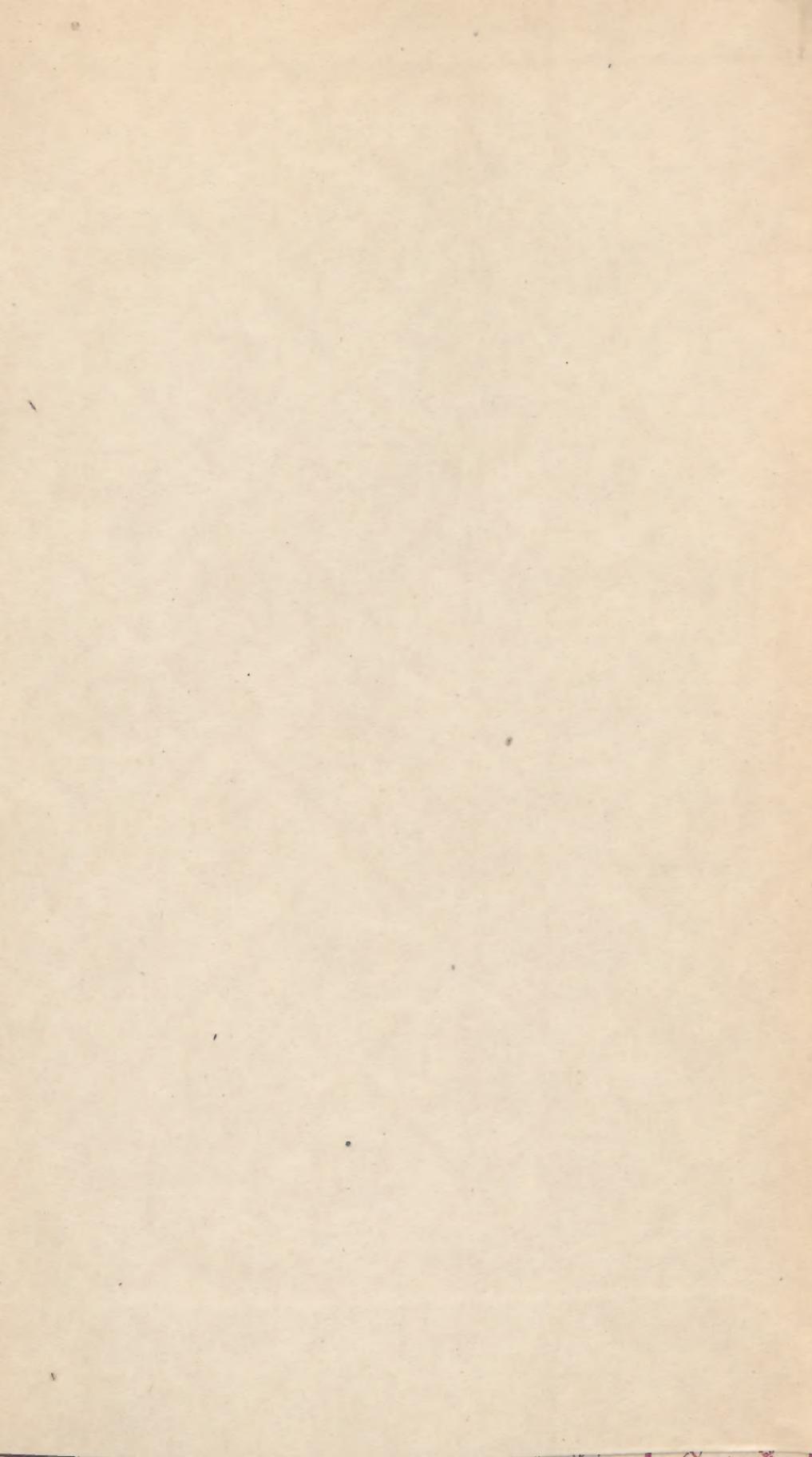
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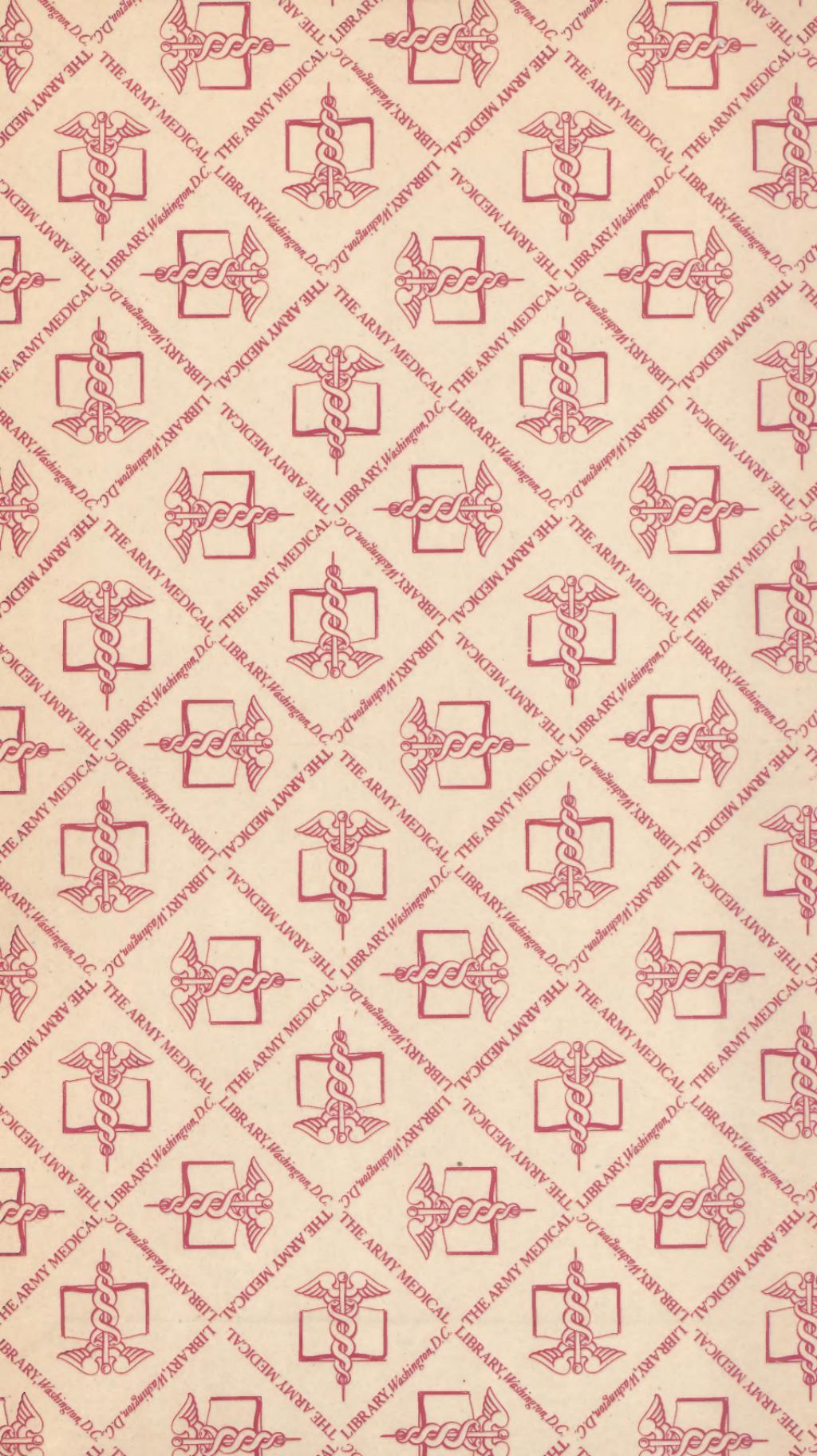
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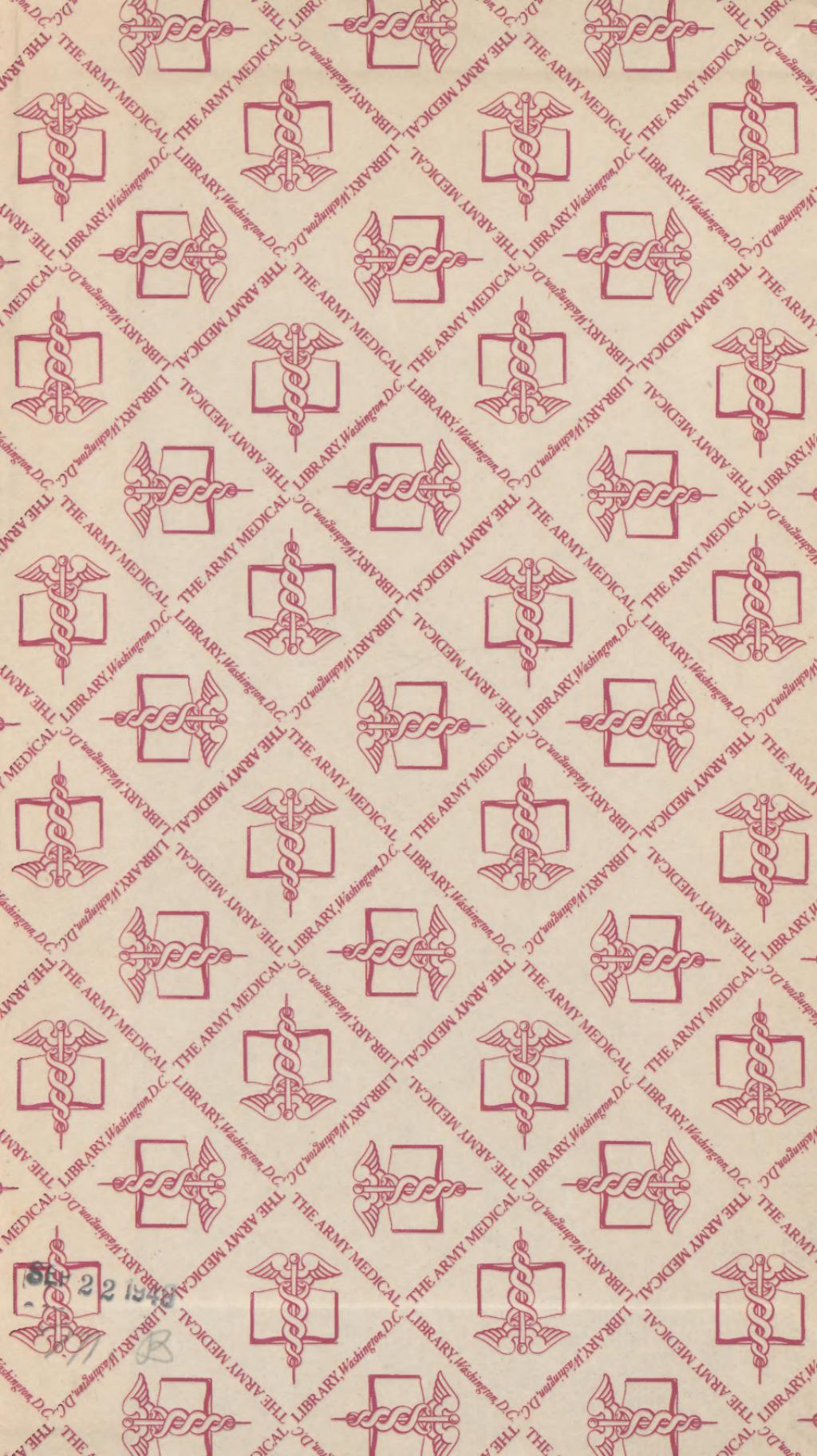
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